Investigating 1500 Years of Dietary Change in the Lower Ica Valley, Peru Using an Isotopic Approach

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This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except where specifically indicated in the text.

No part of this thesis has been submitted for any other qualification.

The length of this dissertation does not exceed the 80,000 word limit set by the Degree Committee for the Department of Archaeology and Anthropology.

Abstract

In the now hyper-arid desert of the south coast of Peru, the natural desiccation of human remains provides a rare and unique opportunity for detailed study into the dietary practices of the people that once lived there. My research investigates the changing subsistence strategies of four groups from the lower Ica Valley from the Early Horizon to the Late Intermediate Period. This area witnessed a dynamic history over this 1500-year time frame, including the emergence and collapse of the Nasca, the spread of influence by the highland Wari empire and the local development of the Ica-Chincha trading society. Yet very little is known about the daily life of the individuals who inhabited this area. By reconstructing their diets it has been possible to examine the economic and land use practices they used as well as the ways in which they created and maintained social relationships using food.

Mummified human remains (bone, teeth, hair and skin) from the four Pre-Columbian groups - Late Ocucaje (c.100 B.C.-200 A.D.), Late Nasca (c.450-650 A.D.), Wari (c.800-1000 A.D.) and Ica-Chincha (c.1200-1400 A.D.) - have been analysed for stable carbon and nitrogen isotopes. The combination of multiple tissues has allowed analysis at the intra-individual as well as the intra- and inter-group levels creating a detailed and nuanced dietary reconstruction that incorporates dietary information about childhood, adulthood and over a short-term (monthly) period. The analysis of multiple tissues from the mummified remains has allowed a critical evaluation of the isotopic relationship between different tissues from the same individuals as well as their use for reconstructing dietary life histories. A review of all tissue isotopic comparisons including the data from this research shows that the relationships are difficult to constrain.

The carbon and nitrogen isotope data show that terrestrial resources, both plant and animal, were the mainstay of the diet in all four periods. Maize was of varying importance over the time frame, with its contribution to the diet increasing over time. Marine resources did not contribute significantly to the diet, despite their abundance in the middens. The strongest case for social differentiation using food is from the Middle Horizon results, which show a high diversity between groups in terms of dietary choice and do not conform to the hypothesis based on the rich botanical data from the valley. From the observations from all four periods the existing theories about the socio-economic structure of the south coast have been critically evaluated in light of this new evidence.

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Chapter 1 Introduction

My research investigates the dietary history of the inhabitants the lower Ica Valley of Peru over a period of approximately 1500 years and the wider socio-economic theories about the south coast during this time frame. I look in detail at both individual and population level dietary choices, investigating how food was used economically, i.e. what was consumed, and socially, i.e. who consumed what. These patterns can be viewed as structured with food having set boundaries and rules governing its usage and role in everyday life (Douglas 1972; Twiss 2007). These rules are also reflected onto the consumers or producers of the foods, and thus in turn onto higher level structures of social or political organisation (Giddens 1984; Twiss 2007). By attaining a more detailed and nuanced view into the everyday lives of the populations who inhabited the lower Ica Valley, better interpretations about how people lived in this arid environment and how social structures shaped and were shaped by their actions can be made. Additionally, the unique approach used in this thesis allows examination of individual life histories and thus the actions of individual people in the past is reconstructed and used to interpret the larger social structures. The interpretations made here are discussed in the context of the current models of south coast existence, examining to what extent the patterns seen in the lower Ica Valley agree with the models based on the neighbouring valleys.

1.1 Research Context

The two millennia before the arrival of the Spanish saw a dynamic history of social and environmental change on the south coast of Peru. It was home to emerging cultures, such as the Nasca, but was also influenced by people of the highlands. Much of the work carried out on the south coast has focused on mortuary and ceremonial contexts, with domestic sites largely ignored. Only recently has this bias started to be addressed by researchers (e.g. Vaughn 2009) but there is still a very limited understanding about the day to day existence of the populations and the individuals who lived in these sites. Thus a large swathe of the archaeological record on the south coast of Peru has so far been neglected. By redressing this balance a more complete and holistic understanding of the past - the way people fed themselves, used and moved about their landscape, interacted within their local and extended networks - should be possible. This thesis reconstructs the dietary choices of south coast populations, choices affected by both social and biological factors. This reconstruction is

made at the population level but also utilises multiple tissues from mummified remains to study the dietary life history of individual people. Thus this research demonstrates how personal histories can be attained from the archaeological record and the value of these for interpreting the past. Use of individual personal histories in this way has not been made on the south coast of Peru before and has only been used in few other archaeological studies. Therefore this thesis demonstrates the strength that this type of analysis has.

The time frame covered by this research is divided into four periods. The earliest period, the Early Horizon and specifically the Late Ocucaje phase (c.200 B.C. to 100 A.D.), is a transitional period into the Nasca culture. Whilst these two cultures are thought to be contiguous and the Nasca naturally developed out of the Ocucaje (also known as the Paracas), it is not clear in the lower Ica Valley when the economic transition from a mainly hunter-gatherer subsistence to an agriculturalist one took place. In the neighbouring basin upstream, agriculture was thought to be the main subsistence base in the Early Ocucaje phase of the Early Horizon (c.800 B.C.) and this area was also home to the centres of political power, with clear social distinctions in existence. I test to what extent the populations studied in this research were practising an agricultural subsistence strategy and whether emerging social hierarchies that have been proposed to have existed at other sites are visible in the diet here. The Nasca then flourished across the south coast in the Early Intermediate Period, uniting people around a common ideology centred at Cahuachi in the Río Grande drainage basin. However, the apparent onset of drought (c.450 A.D.) contributed to the social fragmentation and changes in farming practices that has been observed in settlement pattern data and the use of new water harvesting techniques. The Late Nasca period, which is under investigation here, is thought to have been more socially complex based on the iconography, but the degree to which the south coast people can be considered as one united group is debated. For this period I investigate whether agricultural practices were affected by environmental instability and whether this pressure on resources may have resulted in food being used as a tool to mark social distinctions.

The Nasca eventually collapsed and the Wari from the highlands began to have influence on the coast marking the beginning of the Middle Horizon at approximately 650 A.D.. The Wari empire dominated much of the Andes during the Middle Horizon but the extent to which the Wari were actually present in the coastal hinterlands is debated. Wari material culture and burial practices have been recorded on the south coast occurring alongside local cultural

practices. Similarly, the nature of their interest in the coast at a time of environmental fragility is uncertain. I use data from the lower Ica Valley to explore these two issues.

Finally, this research will explore the Ica-Chincha society of the Late Intermediate Period (1000-1400 A.D.). Very little in known about the Late Intermediate Period in the Ica Valley. Research has generally focused on the valleys immediately to the south of Ica or the Chincha valley to the north. It has been hypothesised, using documentary sources written by the Spanish, that the Chincha were centralised and clearly economically structured and the Ica valley has been proposed as being similarly organised although on a smaller scale. I explore whether the same degree of centralisation and social complexity is visible in the lower Ica Valley through the medium of diet.

On the south coast, the majority of the work has concentrated on the more fertile valleys that constitute the Río Grande de Nazca drainage to the south of the Ica Valley. These archaeological investigations have only scratched the surface in terms of the amount of archaeological remains present and those actually excavated. Models of how the south coast operated in the past have been built largely on survey data and mortuary excavation from the Río Grande area, yet the south coast region is much wider, encompassing more ecological variation, and the past was arguably more complicated than can be understood from these types of data. In a marginal desert environment, such as the south coast of Peru, these variations in the local ecology, even the small ones, may actually have had a significant impact on social structures (Shimada 1982). Without detailed research beyond this core region this problem will never be addressed. By looking at several populations in detail from an area outside of this core, this research is therefore providing a different viewpoint in order to understand south coast archaeology.

1.2 Methods Used in this Research

The question of quotidian activity requires an understanding of the archaeological record at the micro scale and as such requires the investigation of individual and community level actions. Few techniques can achieve a **direct** study of individual actions in the past, which in combination with multiple individuals provides a view of community level actions. Isotopic analysis of human remains is one such technique and is utilised in this research. It is also possible to understand human diets at the micro and macro levels through the study of soft and hard tissues, available thanks to the hyper-aridity of the environment on the south coast.

Broader time frame tissues, such as bone, allow for a community level investigation. At the population level, comparison of the isotopic values of the different tissues are useful in highlighting the range of isotopic values of the resources consumed in the past and how this may have fluctuated. Within each cultural group it will be possible to look at the level of homogeneity in the community or whether elements of social or political status or identity are visible in the diet. The use of hair allows analysis at an individual level but over a time frame that means group trends can be identified and individual positions or groupings within a larger community can seen. These all jointly provide a comprehensive view on how relationships among people, and between people and the environment worked in the past.

The combination of multiple tissues also creates the possibility to examine the life histories of the individuals through comparison of tissues formed during different stages of life. This approach has been seldom used in archaeological studies, yet understand individual choices and actions is a goal aimed for by many researchers, especially those using a post-processualist theory (see for example Hegmon 2003; Shanks and Hodder 1995). Even within archaeological isotopic research the use of multiple tissues has been limited. This is not simply due to tissue preservation as various hard tissues (i.e. different skeletal elements and teeth) can be used in combination (for example see Schroeder *et al.* 2009; Sealy *et al.* 1995; Turner *et al.* 2010; Williams 2005). Thus there exists a area of isotopic analysis that can be employed in answering questions about the way in which individuals lived certain aspects of their lives that has not been fully explored. This research aims to utilise four different tissues (bone, tooth, hair and skin) in order to study individual lives in the pre-Columbian period and how the trends seen within a person's history and those common to multiple individuals can provide a new source of information on the past. For example, a changing diet between childhood and adulthood may indicate the acquisition of a new social status, a change of subsistence regime or a potential migration. Trends in the data may inform on whether this varied on an individual basis or whether there was a common dietary shift in the whole population which occurred at a particular life stage. Whilst it may not be possible to attribute the broadening to a specific age group or food it does help to highlight social differences that are otherwise not apparent in the bulk tissue values when taken separately.

Additionally, comparing the tissues will help to evaluate the applicability of the expected offsets derive from controlled experiments or those that have been theoretically determined. These are usually based on tightly controlled dietary inputs and therefore may not be a good model for free-living populations consuming isotopically mixed diets.

Therefore the approach employed in this thesis not only have methodological implications but address aspects of social archaeology in a new way by studying individual lives within a community.

1.3 Theoretical Basis of this Research

Structuration theory as espoused by Giddens (1984) views the large formalised structures of a society as inherently linked to the actions of the people who operate within the structures. There is a duality to this structure, so that individuals can affect the meaning of the larger structure, which itself can affect human action. This can happen both consciously and unconsciously and human actions must be viewed in the contexts in which they happened (Giddens 1984: 282). In archaeology recreating these contexts can be problematic, but by acknowledging both the social and biological evidence that is available it is possible to go some way towards this. The analysis of multiple tissues is ideal in understanding the structures that influenced society as it deals with both the micro (i.e. individual level) and macro (community) scales. These two scales are inherently linked in the creation and maintenance of structures as the boundaries are constantly reinforced or negotiated through actions at the individual level (Giddens 1984: 282). Thus by taking this viewpoint of the archaeological data from one population in one area (i.e. the lower Ica Valley), it is possible to extrapolate out to larger scale questions concerning the mechanisms employed by societies, and where comparative material exits, these scales can be increased to include a wider area, such as the south coast.

1.4 Research Questions and Hypotheses

Using these techniques I will address a number of smaller questions about each time period, exploring human movement within and interaction with the landscape and the use of food as a social tool on the south coast of Peru. The Andean landscape of coastal deserts rising abruptly into the high Andes stretches for 2000km. Models of self-sufficiency for the Andes based around the idea of using complementary ecologies have been proposed for many societies but the antiquity of such practices is unknown. As such, the relationships observed in this research between the people and their landscape will have an impact on Andean archaeological interpretations. Likewise, the identification of the ways food was used to

create social distinctions within a population will have resonance for much of the Andes, which used the same repertoire of foods as the south coast.

Ultimately, this research will impact in two areas. Firstly, by use of multiple tissues for isotopic analysis has not been attempted in the manner used in this thesis before. This research demonstrates how individual lived lives can be studied and reveal new information that can inform about specific people and also the different histories within a community. Secondly, this research will discuss how the observed patterns and response seen in the lower Ica Valley populations fit with our general understanding of the effects of social upheaval on economic activity at both a micro and macro level in an arid environment. Given the extreme and limiting nature of the environment the discussion will focus on whether the responses of populations were affected significantly by their environment. From my hypotheses for each time period, one of the major issues that is widely applicable is whether increased environmental pressure was a strong enough force to create social differentiation as food resources became limited or whether any social distinctions existed in stable times. Social distinctions can of course be created by other mechanisms that are not environmentally determined. However, by considering all available archaeological evidence for each time period it may be possible to comment on the degree to which the marginal environment had an influence in creating or maintaining these distinctions. My research thus has wider implications for research into archaeological populations in desert environments globally. By comparing my data to other models developed elsewhere in the world (e.g. Park 1992), this research explores the types of human-landscape relationships active in desert environments and whether these are cross-cultural or unique to this environment.

A number of smaller questions are aimed at each cultural period. In turn these will facilitate the understanding of issues particular to each culture, highlighted in Chapter 2.

Three overarching questions that are applicable to all four time periods, building up from the micro to macro scale:

1) What was the diet of the population? How does it complement the published data for the south coast and refine our understanding of the dietary practices used in the past?

2) Are there any dietary differences between subsets of the population in each cultural group, e.g. male versus female? How does this inform on the existence of social distinctions or the differential access to resources in the past?

3) Can larger societal structures, e.g. economic base or trading links, be inferred through dietary records?

By answering these questions, the wider issues should become more apparent as the model for other south coast populations is compared to the data gathered here. I will use the data gathered in my research to test the following hypotheses:

1) By the time of the late Ocucaje the people were practising agriculture as a significant part of their subsistence strategy and were therefore undergoing a cultural transition at a similar time to an economic one.

2) Agriculture was the main subsistence practice in the Late Nasca phases. The Late Nasca period in the lower Ica Valley witnessed high levels of social differentiation due to the decentralisation of society as has been proposed for the valleys to the south. This was partly due to environmental pressures at the time and therefore there is likely to be dietary diversity within the population.

3) The Middle Horizon diets reflect what has been seen in the archaeobotanical record for the research area and therefore there is a return to more of a hunter-gatherer rather than a fully agricultural subsistence regime, possibly similar to the diet seen in the Late Ocucaje. The challenging environmental conditions of the time heightened differences between social groups and thus diversity should be seen in the populations isotopically.

4) The improving conditions of the Late Intermediate Period enabled a return to an agricultural subsistence base. Whilst there was no environmental pressure causing social stratification, the trading basis of the society is likely to have meant there was some stratification.

1.5 Structure of Thesis

This thesis will first discuss the archaeological background relevant to this research, before detailing the specific cemeteries studied. The scientific basis of the research and the implications this has for the types of analysis that have been conducted follows. The samples used in this research and the methods employed to analyse them is detailed in Chapter 5. An overview of the results of the analyses (both osteological and isotopic) is given in the next chapter. Chapter 7 investigates the use of multiple tissue samples to study life histories and by which method this may be most successful. Detailed analysis of each time period for the lower Ica Valley material forms Chapter 8, which is then put into the context of south coast and Andean archaeology in Chapter 9. Finally, the conclusions drawn from this research and the avenues for future research complete this thesis.

Chapter 2 Andean Archaeology and the South Coast of Peru

This chapter discusses the archaeological background as well as Andean archaeological concepts that are pertinent to future discussions. This chapter begins with an explanation of two key economic concepts, which are important to the interpretation and discussion of the results in the second half of this thesis. The chronology and general environment of the south coast of Peru are detailed followed by a review of the current archaeological research that this thesis builds upon. The earliest archaeological evidence, and the earliest population used in this research, from the lower Ica Valley date to the Early Horizon. This research also covers the three subsequent chronological phases - the Early Intermediate Period, the Middle Horizon and the Late Intermediate Period, which are all discussed in this chapter.

Some Spanish terms will be used in this thesis and will be italicised throughout, with an explanation of the term accompanying the first use. Throughout this thesis I will be following the convention introduced by Silverman (1993) that distinguishes between the spellings of Nasca (the culture) and Nazca (in the geographical sense). Latin names of plants mentioned in the text will be given at the first mention of the common name only.

2.1 Andean Economic Concepts

In pre-Columbian times in the Andean region there is little evidence for marketplaces (Murra 1985a). This meant that different types of exchange had to be carried out in order for people to have resources that they could not obtain directly. There are three types of exchange that could have occurred - reciprocity, redistribution and market exchange. The landscape of the Andes, with its diverse production zones positioned at different altitudes, naturally restricted the production of goods to certain areas. The structured exploitation of these multiple zones is referred to as ecological complementarity. The positioning of these production zones had a bearing on the type of exchange used. Another system that affected the way in which goods were exchanged was the kin-based *ayllu*. Both of these concepts and their bearing on how goods were exchanged are discussed in more detail below.

2.1.1 Ecological Complementarity

In the 1970s John V. Murra developed a model of economic self-sufficiency for certain parts of the Andes (including my study area) which he termed the 'vertical archipelago' (Murra 1972). Its basic idea is that permanent colonies belonging to a centre of power are spread

throughout a range of production zones and ecologies that divide the Andes vertically (see Figure 2.1), with each group utilising the land in the fashion most suitable for that location, whether that be farming a particular crop, herding animals or harvesting natural resources, such as salt (Murra 1972). The colonies could form multi-ethnic islands within one ecology as different groups shared certain lands, most notably the *puna* (>3900 m.a.s.l), each acting as a colony for different a group (Murra1972). This form of economic organisation allowed ethnic groups direct access to a wider range of resources through redistribution, in the absence of a market place economy (Murra 1985a; Salomon 1985). This was postulated by Murra (1972) to be a pan-Andean practice, used by both large scale groups, e.g. the Lupaqa (numbering 100,000+) and small scale groups, such as the Chupachu (numbering 10,000 people). This type of economic organisation is still evident in highland communities today despite centuries of Spanish colonial and Republican rule (Murra 1985a).

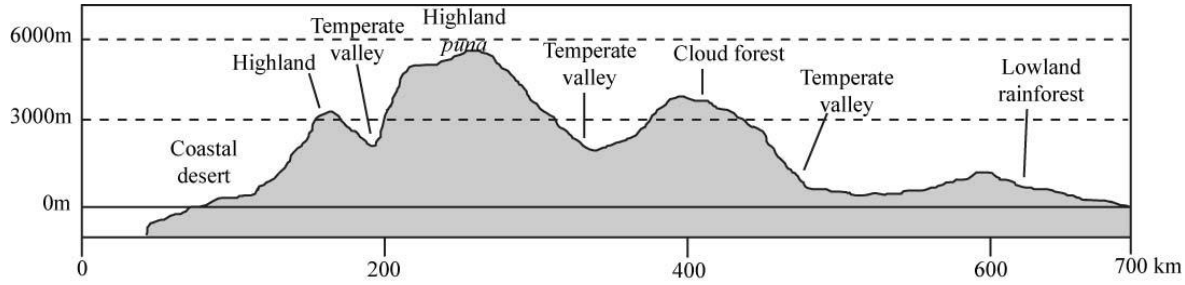

Figure 2.1 Vertical transect of the Andes, illustrating how varied the landscape is over a relatively short horizontal distance.

This model developed from the study of documents has formed the basis of how economic transactions have been viewed in Andean archaeology ever since. It was based upon observations recorded by the Spanish chroniclers of communities, like the Chupachu, who still retained economic interactions at the time of the Inca (Murra 1972). Many studies that implemented Murra's hypothesis concern the latter stages of pre-Columbian history, or derive from ethnohistorical accounts (Durston and Hidalgo 1997; Muñoz *et al.* 1997) and the antiquity of this system has been explored in several different case studies but it is difficult to document in the archaeological record (Llagostera 2010; Mujica *et al.* 1983; Muñoz *et al.* 1987; Muñoz *et al.* 1997).

This idea has been taken up by other authors and developed critically as well as reworked by Murra himself. In larger societies this system would have been weakened by the lord/*mitmaqkuna* (forced resettled labour) relationship which undermined common goals of reciprocity (Murra 1985b). This system has also been proposed by Murra (1985b) as operating with the majority of the population of the ethnic group based in the *altiplano*, the high plains around Lake Titicaca and so it is a highland-centric model. One critiqued aspect of the model is what constitutes a colony and what the nature of goods swap was, i.e. whether it was reciprocity, redistribution, or a commercial exchange (Llagostera 2010), and these aspects are of particular importance when considering the larger societies with dominant/subservient hierarchies. The number of colonies needed to make it a vertical archipelago has also been questioned. Murra's view (1985b) was that the larger the ethnic group or society the greater number and more distant colonies they could maintain. Llagostera (2010) has instead proposed the idea of 'uphill' and 'downhill' populations, which formed a duality, rather than a string of colonies. For instance he doesn't believe that in the Middle Horizon there was a vertical archipelago as there were no Tiwanaku colonies in the lowlands (with the exception of the Osmore valley) partly due to the massive ethnic mix hindering the social unity needed for redistribution. The socio-economic organisation of the Late Intermediate Period in northern Chile, on the other hand, was perfect for the archipelago system to be implemented (Llagostera 2010). Likewise van Buren's analysis of the model concludes that it is only applicable under certain conditions and at certain levels of socio-economic organisation, which can be difficult to discern in archaeological populations (van Buren 1996). A number of different systems of complementarity have been put forward by Salomon (1985), which see varying levels of access to resources and centralisation of the group in consideration, based on actual Andean ethnographic examples.

Ecological complementarity has been hypothesised to work differently on the coast. It was more difficult for coastal societies to have colonies in the highlands and therefore they operated within a sphere of exchange (*treque*) rather than redistribution (Rostworowski 2004). Coastal groups were able to produce resources both via fishing and irrigation agriculture inland, which could then be traded for items from the highlands and jungle. This could operate across valleys, i.e. was *horizontally* orientated (Salomon 1985; Shimada 1982). Based on the archaeological materials recovered from sites in the north of Peru, Shimada (1982) believed that the Moche subsisted on resources moved horizontally across valleys, whereas non-food raw materials such as metals were attained vertically from the highlands.

Murra (1985b) does not see this as detracting anything from his vertical model as both systems could work alongside each other.

2.1.2 The *Ayllu*

The concept of the *ayllu* is believed to have operated throughout the pre-Columbian era and is still in existence. The *ayllu* is a kin-based social structure that tied people together in both social and economic terms ensuring the group could be self-sufficient (Moseley 2001). Members of the same *ayllu* shared a common ancestor or place of origin (D'Altroy 2002). The *ayllu* emphasises unity between the members as well as providing a hierarchy. It also incorporates aspects of duality, as the constant expansion of families creates separate lineages, which all fall under the auspices of the same *ayllu*. In order to retain property and resources within an *ayllu*, intra-*ayllu* marriages would take place, ensuring self-sufficiency for future generations (D'Altroy 2002; Moseley 2001). The *ayllu* was a system used by all strands of society, including the Inca royalty (D'Altroy 2002).

A fundamental aspect of the *ayllu* is that the responsibilities undertaken by the members are done on the basis of reciprocity - that something of equal value will be given back to them in return for their labour or produce at some point in the future (Gose 1994; Moseley 2001). This is essential in an environment such as the Andes where specific but infrequent tasks require the assistance of more individuals than would be supported in a household. When labour is exchanged, the members who are receiving the help are also expected to feed those that contributed (Gose 1994). Food is the most frequently exchanged commodity outside of labour (Moseley 2001). It is often mentioned hand in hand with the vertical archipelago as each *ayllu* try to achieve this self-sufficiency. Indeed, even in modern times an *ayllu*, where possible, will have access to a range of different types of land in a variety of production zones (D'Altroy 2002). The vertical archipelago then can be seen to operate at many different scales and at different times, from the small scale kin-based *ayllu* to the state level.

2.2 Chronology used in this Thesis

The chronology used in this thesis shall follow that of Beresford-Jones *et al.* (2011b), which is in turn based on the ceramic classifications of Hecht (2009) and Silverman (1993), and radiocarbon dates by Unkel and Kromer (2009), summarised in Figure 2.2. These works use the period divisions first proposed by Rowe (1960) and the ceramic sequence first proposed by Menzel *et al.* (1964) that were based on material from the Ica Valley. The term 'horizon' is

used when a single artistic style is common to populations over a large area and implies some sort of cultural unity as opposed to the 'intermediate periods' which reflect cultural diversity with local styles (Rowe 1960). I have chosen to use this chronology here as it is the most relevant to my research, developed on material from the immediate area and has been used by scholars who have published the most comparable material to mine (for instance Beresford-Jones *et al.* 2011b; Reindel and Wagner 2009). Elsewhere different chronologies are used in Andean archaeology, for example Lumbreras (1974) uses the divisions Archaic, Formative, Regional Developmental etc. The radiocarbon dates given for the divisions of Rowe's periods also vary by region as they are defined by the arrival of a certain style. Naturally this would not have been instantaneous in an area as large as the Andean region.

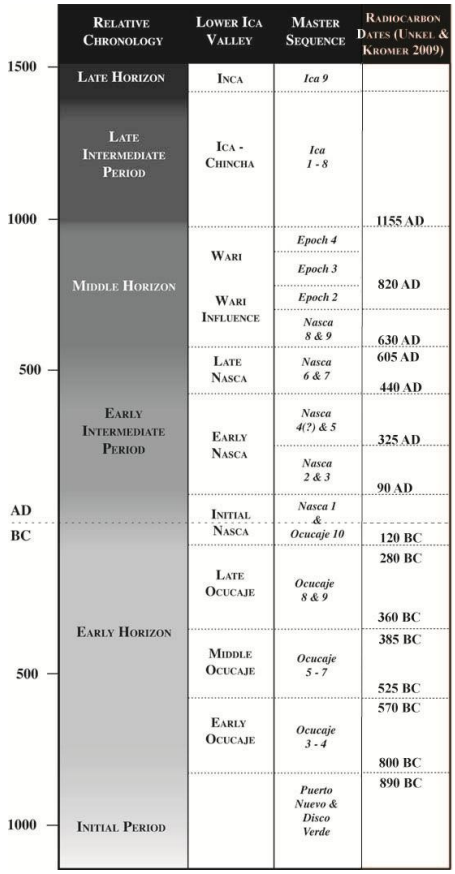

Figure 2.2 The chronology used in this thesis. The radiocarbon dates are from the work by Unkel and Kromer (2009) in the Palpa region. The figure is modified from Beresford-Jones et al. (2011b: fig 2).

2.3 The Geography of the Ica Valley

The Ica Valley is located on the south coast of Peru, approximately 300km south of the modern capital Lima. To the north of the Ica Valley lie the Chincha and Pisco Valleys as well as the Paracas Peninsula, and to the south the Rio Nazca de Grande drainage basin and the Acarí Valley (Figure 2.3). This area roughly defines what archaeologists refer to as the 'south coast' of Peru.

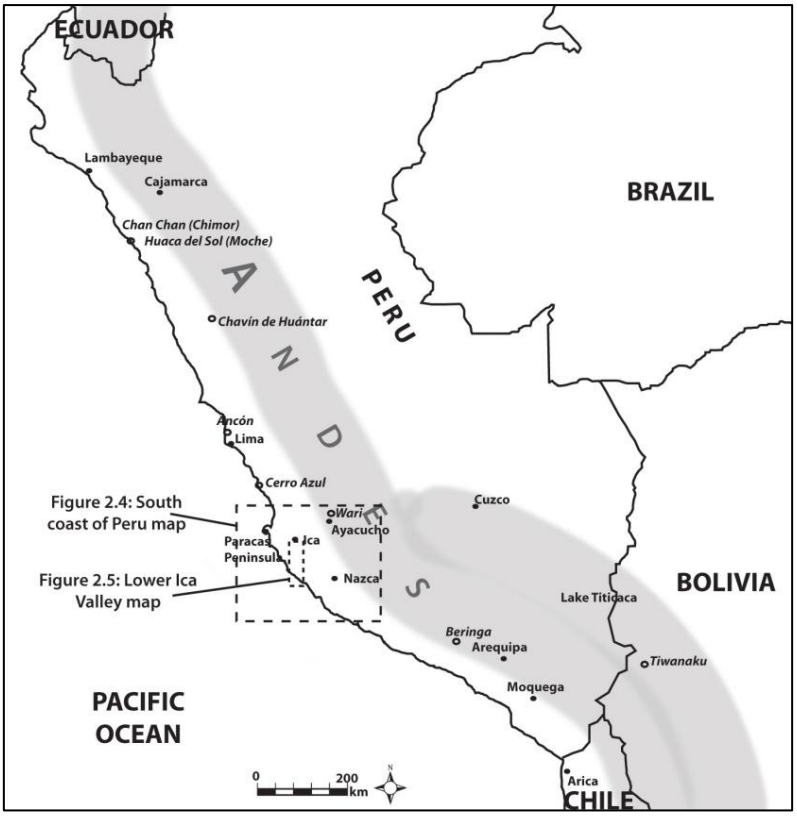

Figure 2.3 Map showing the location of the south coast region and other archaeological sites mentioned in this thesis. Sites are identified by open circles and modern places by closed circles.

The environment of the south coast region today is one of arid desert, with virtually no rainfall and this is thought to have been the case for at least the last 2000 years (Knudson 2009). Despite a number of rivers and their tributaries, the region has very little naturally irrigable land. This has been proposed as one of the reasons why complex societies flourished here much later than on the north coast of Peru (Silverman 1996). The south coast has been described as a strip of desert approximately 90km wide from the sea to the foothills (Eitel and

Mächtle 2009), with the rivers traversing this in an east-west direction with the exception of the Ica river that travels in a north-south direction (see Figure 2.4). The rivers flow seasonally after the rains in the highlands, and often in the lower reaches there is only surface water between January and March in modern times. This area is hyper arid with the only other source of water being the coastal fog that brings moisture to the *lomas* – hills approximately 1000 m.a.s.l. that form a barrier between the sea and the wide coastal strip. The area has been described as an "ecologically very sensitive tropical environment" that is a high-risk region for agriculturalists (Eitel and Mächtle 2009:20). The lack of rainfall in the past is evidenced by the use of adobe for construction from the Paracas period onwards (Eitel and Mächtle 2009).

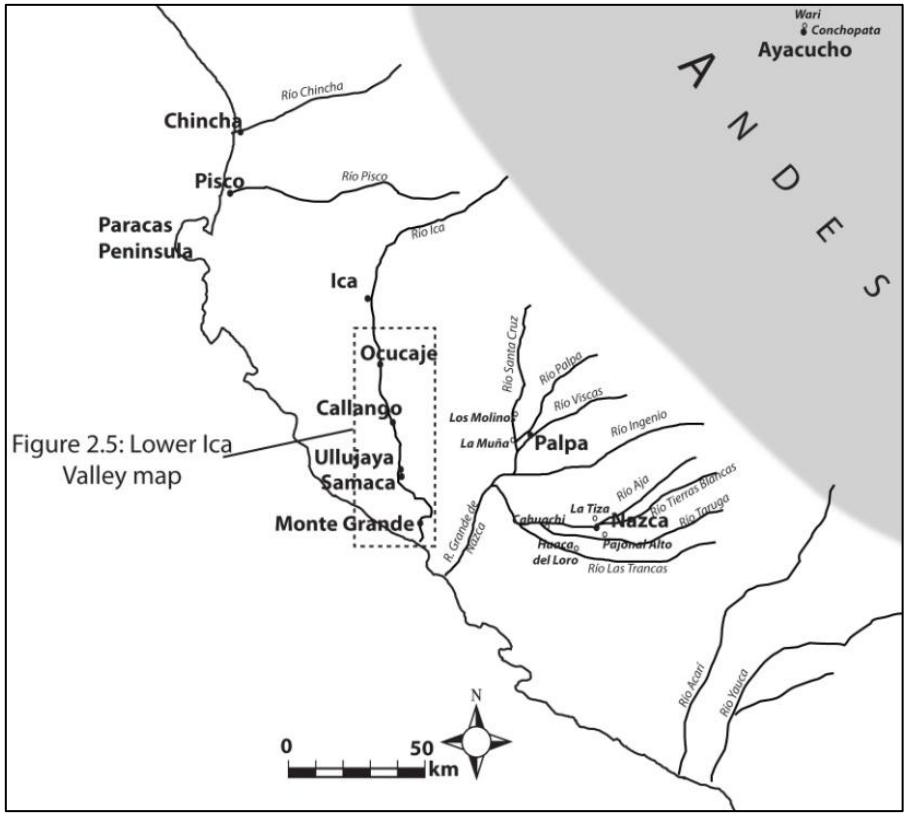

Figure 2.4 Map of the south coast region of Peru. Specific sites are identified by open circles.

The Ica Valley can be divided into three sections – upper valley, comprising of the source of the river at an altitude of 4503 m.a.s.l. and the portion in the foothills; the middle valley, that includes the modern city of Ica; and the lower valley, which includes the area from the

Ocucaje Basin to the mouth of the river at the Pacific ocean (see Figure 2.4 and 2.5). The material used in the research is from the Ullujaya and Samaca basins located in the lower part of the valley, approximately 20km from the sea as the crow flies, although the river continues on a longer winding course through the Monte Grande basin before reaching the sea. These lower valley basins benefit from a higher ground water table and therefore despite only a seasonal presence of the river the Ocucaje and Callango basins were favourable locations for agriculture (Massey 1991; Menzel *et al.* 1964). The Samaca and Ullujaya basins, conversely, had much lower agricultural capacity due to a comparatively decreased water availability and less cultivatable land (Massey 1991).

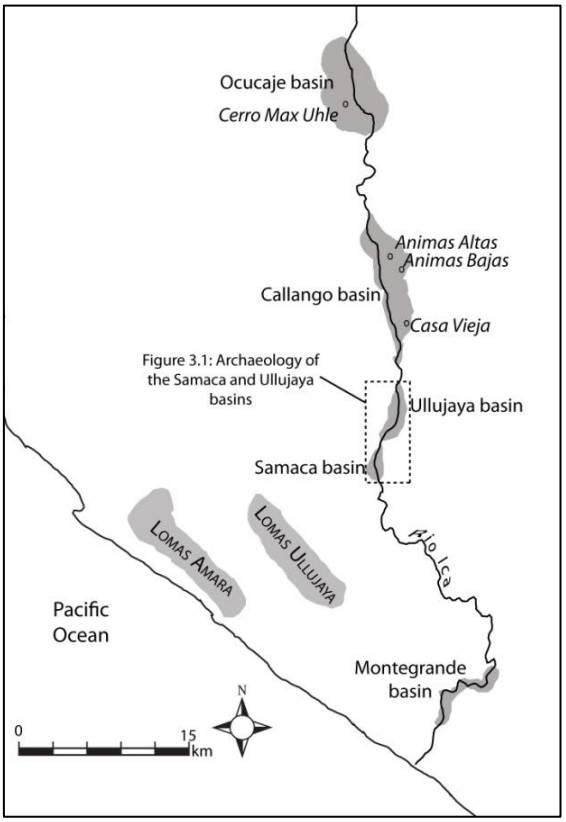

Figure 2.5 The lower Ica Valley. Archaeological sites are marked by open circles.

For ease of reference, Figures 2.3, 2.4 and 2.5 detail the location of the main sites in the south coast that will be mentioned in this chapter.

2.3.1 The Isotopic Landscape

There are three main ecotones in the lower Ica Valley - the valley basins, the *lomas* and the coast. These three areas provide different key resources that could have been exploited in the past by the populations living there. The valley basins are the immediate area of the cemeteries used in this research and thus provide the nearest resources, including fresh water. The water from the river, as well as the high water table in the Samaca and Ullujaya basins (Massey 1991), enables vegetation to grow along the river's edge and approximately half a kilometre either side. The vegetation in the valley has been argued to have been transformed from a riparian woodland in the Early Horizon to an agricultural, artificially irrigation landscape during the Early Intermediate Period, remaining this way throughout the Middle Horizon and Late Intermediate Period (Beresford-Jones *et al*. 2011b). Both wild and domestic plants are seasonally available, although many of them can be dried and stored for long periods of time. The wild edible plants include huaranga (*Prosopis* sp.), tomatillos (*Solanum pimpinellifolium*), sedges (Cyperaceae), chenopods and amaranths (Chenopodiaceae and Amaranthaceae), and cacti (Cactaceae) (Cadwallader *et al*. 2012). The animals likely to have been present in this ecotone in the past include domesticates, such as llama (*Lama glama*) and guinea pig (*Cavia porcellus*), and wild animals, such as foxes, birds and rodents. There is also the possibility of fresh water resources from the river being consumed when available (in modern times between January to March). These would include crayfish (Parastacidae) and riverine birds.

The *lomas* hills form a natural barrier between the Samaca and Ullujaya basins and the coast, running parallel to the sea (see Figure 2.5). They are located approximately 20 km from the two basins in a straight line across the desert. There is no fresh water supply on the *lomas* yet they are able to sustain vegetation. In the nine dry months of the year (September to May) the principal species are cacti and stumps of grass (*Stipa pachypus*) (Whaley *et al*. 2010). During the winter months (June to August) there is a near continual presence of a coast fog, which allows seeds of other vegetation, such as *Astragalus* sp. (Fabaceae), *Nolana* sp. (Solanaceae), *Suaeda* sp. (Chenopodiaceae) to germinate and bloom (Whaley *et al*. 2010). Guanaco (*Lama guanicoe*) are attracted by this bloom of vegetation in the winter months. In addition this ecotone supports large colonies of *Bostryx* snails who are only active during the winter months, estivating for the remaining part of the year, geckos (*Phyllodactylus* sp.) and only one species of bird, *Geositta peruviana* (Whaley *et al*. 2010).

The coast is located just beyond the *lomas* and the Humboldt current of the Pacific makes this one of the richest marine resources in the world. Shellfish, fish, sea mammals and see birds all reside at the coast. The shellfish include a wide variety of clams, mussels and oysters (see Tieszen and Chapman 1992). Sea mammals include sea lions (*Otaria flavescens*) and dolphin (*Delphinus delphis*). The range and type of birds is numerous, including pelicans (*Pelicanus* sp.), boobies, gannets and commerants (Sulidae family). The fish range in size from very small anchovies (*Engraulis ringens*) to large species such as *corvina* or sea bass (C*ilus gilberti*) and whales during their migrations. Fish are caught in modern time both by net, fished from the shore and by boat. Additional resources at the coast are seaweeds and guano, although there is no source of guano immediately in the area of the lower Ica Valley. There is an abundance of these coastal resources available year round.

These three areas can be characterised isotopically to different extents based on currently published research. There is likely to be a considerable amount of overlap between the three zones, although some differences are clear (see Figure 2.6). The isotopic composition of the ecotones has not been well defined in the literature and thus it is difficult to precisely characterise them and thus only a general description of the isotopic characteristics is given here.

It is difficult to fully characterise the basins, as the exact plant composition of these in the past is unknown and would have varied over time. However, the main domesticates likely to have grown there will be C_3 plants - legumes, squash, possibly tubers - with maize and kiwicha the C_4 domesticate in the Andes. The wild plant composition is estimated to be in the region of one third C_4 and two thirds C_3 in this area (Cadwallader *et al*. 2012). All of the plants, with the exception of legumes, are likely to have a similar $\delta^{15}N$ values. In the case of legumes their $\delta^{15}N$ values would be several parts per mil lower (see Section 4.1.3). The animals in the basin would be expected to be one trophic level above the plants (see Section 4.1). The freshwater resources would have a C_3 signal and high $\delta^{15}N$ values.

The *lomas* resources have been poorly characterised isotopically. C_3, C_4 and CAM species are present (Thornton *et al*. 2011; Whaley *et al*. 2010). The nitrogen isotopes of these plants would be elevated in comparison to those from the valley basin. Again, the isotopic values of the animals feeding off of these plants would be a trophic level higher. Perhaps the only exception to this is guanaco who are nomadic in the landscape and will also have an isotopic signal that may reflect consumption of plants from valley basins (Cadwallader *et al*. 2012).

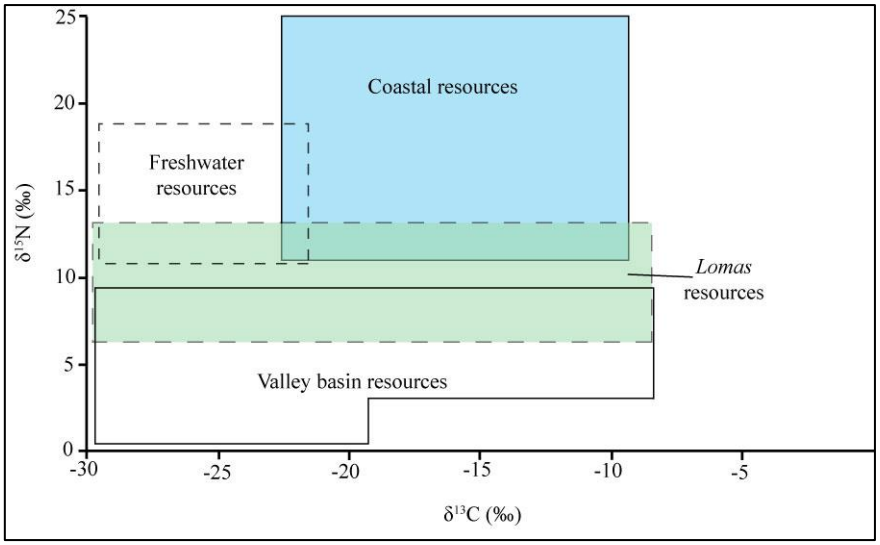

Figure 2.6 General isotopic composition of the different ecotones in the immediate lower valley area.

Coastal resources for Peru have not been isotopically defined in the literature. One study from Arica in north Chile (Tieszen and Chapman 1992), which is of a similar ecology to the desert coast of Peru, has isotopically defined a number marine resources categorised as fish, invertebrates, vertebrates and plants. Whilst these resources have a fairly wide carbon isotope range, they all have significantly elevated nitrogen isotope values in comparison to other resources and thus can be distinguished from other resources.

In summary, the three ecotones all offered different food resources that would have been in easy reach of the Samaca and Ullujaya basins. Seasonal availability would mostly be a concern with the *lomas*, although resources such as the *Bostryx* snails would have been available all year. It should be possible to distinguish between the three ecotones isotopically, although there is overlap between the groups.

2.4 The Archaeology of the South Coast

2.4.1 Early Horizon

Like all Horizon periods, the Early Horizon is characterised by the spread of one material culture over a substantial area. In this case it is Chavín art and iconography, which was replaced on the south coast by the Paracas culture (also called Ocucaje) in the later stages of this period. Here both cultures are briefly described, so as to set a context for the issues pertaining to the Late Ocucaje population used in this research.

Early Horizon - Chavín

The Early Horizon is defined by Rowe (1960, 1962) as the period between the first instance of Chavín influence in the Ica Valley until the replacement of resin painted pottery with polychrome slip painting. The evidence for early Chavín-influenced ceramics or textiles from the Ica Valley comes from a small number of artefacts, few of which have been radiocarbon dated. These place the start of this period as 800 B.C. (Paul 1991; Unkel and Kromer 2009), which fit well with the radiocarbon dates for Chavín de Huántar, the birthplace of the Chavín culture (Burger 1988, 1992).

Chavín de Huántar is situated in northern highlands of Peru at 3100 m.a.s.l. (see Figure 2.2) and was a monumental, ceremonial site, with clearly religious structures. Its influence spread over 500km to the south coast as well as to the north coast and throughout the highlands up to the Cajamarca region (Burger 1988). Motifs similar to those found in Chavín de Huántar appear on textiles and ceramics in the Ica Valley where the influence was strongest on the south coast (Beresford-Jones *et al.* 2011b; Burger 1988, 1992; Silverman 1996; Wallace 1962) and it is thought that Chavín ideology spread through iconography as opposed to political or economical control or occupation.

Early sites of this period on the south coast, including those in the Ica Valley, are difficult to identify due to the ephemeral nature of the material record. Deposits are often no more than ceramic scatters or ceramics infills of later architectural structures and thus have not enabled a detailed study of the early part of the Early Horizon (DeLeonardis 2005). Few of these sites have been excavated - namely Cerillos in the upper Ica valley, as well as sites in the lower Ica valley in Callango and Samaca (Beresford-Jones *et al.* 2011b; Massey 1991; Silverman 1996). Cerillos has several phrases of reconstruction of both habitation and ceremonial features (Lumbreras 1974; Wallace 1962). Chavinoid ceramics are common at the sites in the Ica Valley and attest to the spread of the Chavín influence to the south coast yet the presence of ceramics with local traits shows that Chavín only had an influential role and not a supplanting one (Beresford-Jones *et al.* 2011b; Wallace 1962). DeLeonardis (2005) suggests that contact between different communities within the whole Ica Valley as well as with those outside of it, was already established in the early phases. Silverman (1996) proposed that the contact, already established between the Ica Valley, in particular, and the highlands, as well as the social and economic complexity brought about by the influence of Chavín, paved the way for greater cultural complexity on the south coast. This complexity was seen initially with the Paracas stylistic tradition and continued with the florescence of the Nasca.

Early Horizon - Ocucaje

Chavín influence was superseded by the Paracas stylistic traditions in Ocucaje Phases 8 and 9 (Massey 1991; Silverman and Proulx 2002), dated from 360 to 280 B.C. (Unkel and Kromer 2009). The Paracas culture was first encountered on the Paracas Peninsula (see Figure 2.4) by Julio C. Tello in the early 20th century. Two distinct Paracas traditions have been identified - Paracas (also called Cavernas) and Topará (also called Necropolis).They apparently represent two different societies which are both chronologically and spatially separate (Silverman 1991; Silverman and Proulx 2002), evident in the ceramics as well as the burial patterns (Silverman and Proulx 2002). The Paracas (Cavernas) style pottery has been found in all of the southern coastal valleys from Chicama to Nazca (Lumbreras 1974). The Topará style is closely associated with the sites excavated on the Paracas Peninsula by Tello, including the numerous burial chambers containing well preserved mummified remains.

Material culture of Paracas origin from the Ica Valley is referred to as Ocucaje to distinguish it from the remains on the Peninsula (Menzel *et al.* 1964; Silverman and Proulx 2002). Apart from the famous burial sites on the Paracas Peninsula, most of the work on Paracas ceramic material has been carried out in the Ica Valley (Menzel *et al.* 1964), although it is applied across the south coast.

Surveys of the Ica Valley (Beresford-Jones *et al.* 2011a; Cook 1991; Massey 1986) have identified many of the Late Ocucaje sites, whereas in neighbouring valleys, surveys have not been as extensive (Silverman 1991). The number of settlements in the Ocucaje 8 period increased dramatically occupying the length of the valleys, with many of these continually occupied in the following Ocucaje phases as well (DeLeonardis 2005; Massey 1991; Menzel *et al.* 1964). The settlements of the lower valley were often on the top or slopes of hills suggesting that a defensive location was important (Massey 1991; Menzel *et al.* 1964:104, 210). Several large late Ocucaje sites have been recorded for the Callango basin including Animas Altas and Animas Bajas (Figure 2.5), with habitation sites concentrating in this basin from Phase 8 (Massey 1991). Animas Bajas was the largest Phase 8 site in the Ica Valley, with surviving large buildings and abundant habitation refuse (Massey 1991). Occupation at this time in the Ocucaje basin and in the middle valley was small in comparison with no sites comparable in size to Animas Altas (Massey 1991).

During Phase 9, the middle and lower Ica valley saw regional growth and consolidation (Massey 1991). Sites from Phase 8 were occupied into Phase 9 but less densely indicating

relative stability in the region (Massey 1991). Animas Altas replaced Animas Bajas in Ocucaje 9 as the major settlement in the Callango basin and of the whole Ica Valley, with its size and complexity suggesting it was the 'capital' of the lower valley area (Massey 1991). This site contains decorated walls depicting mythological beings including the Oculate Being yet ritual abandonment took place shortly after its creation (Massey 1991). A new, smaller centre, Cerro Max Uhle, was subsequently established in the Ocucaje basin and continually occupied until well into the Early Intermediate Period (Massey 1991). Monumental and habitational architecture in this phase is also recorded at Tajahuana, in the middle Ica Valley, and Carhua, near the Bahía de la Independencia (Lumbreras 1974; Massey 1991; Menzel *et al.* 1964). Based on settlement pattern data, the late Ocucaje period is hypothesised to be comprised of a confederation of valley-wide socio-political units (DeLeonardis 2005; Massey 1991). Whilst Callango appeared to be the centre of power in Phase 9 (Massey 1991), changing political relationships meant this did not last long.

Ocucaje phase 10 marks the start of what is referred to 'Initial' or 'Proto Nasca', which also spans ceramic phase Nasca 1. Radiocarbon dates put this transitional period as 120 B.C. to 90 A.D., although this is based on a small number of samples and leaves a hiatus in the dates between Ocucaje phases 9 and 10, which does not tally archaeologically (Unkel and Kromer 2009). Menzel *et al.* (1964) put the centre of power in Ocucaje at this time believing the shift in style and decrease in diversity reflects a change in the political relationships. During Ocucaje 10 many of the sites inhabited in the previous phase were seemingly abandoned and the population of the Ica Valley dispersed into small sites throughout the valley (Massey 1991). The Callango basin appears to have been abandoned with the collapse of the regional authority and decentralisation. Only the Ocucaje basin site seem unaffected, with Cerro Max Uhle occupied without any clear evidence for population change and new sites established to cope with a population expansion (Massey 1991). This Initial Nasca phase is thought of as a transitory period from the Early Horizon to the Early Intermediate Period. The cultural transition is clear from the change in style in the material record but it has largely been unstudied beyond this.

The Nasca style developed directly from the Paracas culture both in terms of ceramics and population (Silverman and Proulx 2002). Indeed, the distinction between Paracas and Nasca in the ceramic sequence laid out by Menzel *et al.* (1964: 2) is essentially "an arbitrary one", used to make chronological distinctions.

Diet During the Early Horizon

In the Samaca basin of the lower Ica Valley, archaeobotanical evidence from the early part of the Early Horizon (c.750 B.C.) suggests that the populations were reliant on wild plant foods and marine and *lomas* resources (Beresford-Jones *et al.* 2011a; Beresford-Jones *et al.* 2011b). The only domesticate found in these Early Ocucaje middens was cotton (*Gossypium* sp.). Other sites dating to the Early or Middle Ocucaje have recorded the presence of domesticated remains, such as maize (*Zea mays*), squash (*Cucurbita* spp.), beans (*Phaseolus lunatus*, *P. vulgaris*), potato (*Solanum tuberosum*), jíquima (*Pachyrrhizus tuberosus*) and quinoa (*Chenopodium quinoa*), although these observations are not from systematic archaeobotanical research (DeLeonardis 2005; Lumbreras 1974: 59; Wallace 1962). Anecdotal evidence from the Late Ocucaje (c.100 B.C.) in the lower Ica Valley suggests that maize, manioc (*Manihot esculenta*), squash, peanut (*Arachis hypogaea*) and pacay (*Inga feuillei*) were all present at the time, although this again is not based on dedicated archaeobotanical investigations (Beresford-Jones *et al.* 2011b). Thus it could be argued that the exploitation of these domesticates occurred later in the Samaca and Ullujaya basins of the lower Ica Valley, where agricultural conditions were less favourable (Massey 1991). However, given the location and concentration of settlements around irrigable land, it is reasonable to suggest a predominately plant-based subsistence in the Ica Valley, whether those plants were domesticated or wild.

For the populations residing near the coast, marine resources were the mainstay of the diet (Horn *et al.* 2009). For those residing slightly further inland, marine resources, as well as hunting and gathering in the *lomas*, remained an important supplement to agriculture or plant based subsistence (Lumbreras 1974:59) as can be seen in the lower Ica Valley midden material (Beresford-Jones *et al.* 2011a; Beresford-Jones *et al.* 2011b). Silverman (1996) has reasoned that the reliance on marine resources in general on the south coast was relatively low because, unlike the northern valleys, the Ica and Nazca rivers did not drain into wide deltas. This is supported by an apparent lack of maritime resources recovered from sites further inland, such as Cerillos (Wallace 1962)

Summary

In the late Ocucaje times the Ica Valley was to some degree centralised with important centres most likely serving a ritual purpose as well as housing a resident population. A shift is hypothesised that would have moved power from Callango to Ocucaje and thus further away from the populations in the Samaca and Ullujaya basins with whom we are concerned with here. Sites such as Animas Altas, Bajas and Cerro Max Uhle attest to the increasing social

complexity of this period and thus elude to the creation of social distinctions. In the Callango and Ocucaje basins subsistence is based on an agricultural economy, which began in the early part of the Early Horizon. However, in the Samaca and Ullujaya basins the adoption of a predominately agricultural system seems to have been delayed, with only hints of agriculture being important in the Late Ocucaje period. Marine and *lomas* resources also appeared to be more important than hypothesised for this valley.

2.4.2 Early Intermediate Period

The Early Intermediate Period is seen as a continuation of the traditions of the Early Horizon and is characterised on the entire south coast by the florescence of the Nasca culture. Recent radiocarbon dating (Unkel and Kromer 2009) puts the start of the Early Intermediate Period as 90 A.D., dividing it into Early Nasca, ceramic phases 2 and 3 (90-325 A.D.); Middle Nasca, ceramic phases 4 and 5 (325-440 A.D.); and Late Nasca, ceramic phases 6 and 7 (440-605 A.D.). Nasca 1 ceramics are seen as a derivative of Ocucaje 10 and therefore belong in the Initial Nasca transition and Nasca 8 and 9 are now considered part of the Middle Horizon sequence (DeLeonardis and Lau 2004; Silverman 1993; Silverman and Proulx 2002) - see Figure 2.2.

An absence of Early and Middle Nasca human remains from the lower Ica Valley means that this time period is not addressed directly in this research. However, the background to it is discussed briefly here in order to put the Late Nasca period into context.

Early Nasca

The Nasca period saw a population increase thought to be driven by internal prosperity as mtDNA analysis shows little evidence for an influx of migrants (Fehren-Schmitz *et al.* 2009). Given the limitation on which areas could be settled, this meant an increase in the population density, which in turn accelerated social differentiation (Isla 2009).

The most important Nasca site is Cahuachi, located on the south bank of the Río Nazca. It consists of a series of ceremonial structures including large mounds and buildings built in Nasca 1 (Silverman 2002: 164). Nasca 2 saw the expansion of Cahuachi and its ceremonial role, which peaked during Nasca 3, when the ceramic iconography had reached a technological and aesthetic peak (Silverman 2002: 154, 165). Cahuachi apparently never had a significant resident population but was used instead for ritual purposes (Piacenza 2005; Silverman 2002: 154; Valdez 1994). During this phase an abundance of Nasca settlements were occupied throughout the Río Grande de Nazca drainage area (Silverman 2002: 165).

Several other civic-ceremonial centres have been identified as Nasca 3 in the Palpa and Nazca valleys but not further to the south (Silverman 2002: 166).

It has been proposed that Cahuachi was also a major site of polychrome ceramic production, from the very start of the Nasca epoch. The ceramics were then distributed throughout the immediate region and possibly further afield, thus controlling the manufacture and distribution of iconography (Vaughn *et al.* 2006; Vaughn and Van Gijseghem 2007), although this is yet to be shown on a wider scale. What is clear is that fineware Nasca ceramics are found in both ceremonial and domestic contexts alike (Silverman 2002: 153). Due to its presence in domestic contexts it has been suggested that fineware pottery was a mechanism for maintaining relationships among distant communities through sacral settings and local social order (Silverman 2002: 153). This relationship is also hinted at by the near absence of Early Nasca burials outside of Cahuachi (Beresford-Jones *et al.* 2011a; Isla 2009). The site is hypothesised to be the burial ground for the Early Nasca populations from across the Nasca sphere. Isotopic analysis of 22 burials from Cahuachi has indicated that the burial population was derived from the 'local' area (n=7) as well as others who had spent the last 20 years of life in the sierra (n=10), or nearer the coast at altitudes below 300m (n=5), although these samples came from museum collections and therefore could not be attributed to any specific Nasca phase (Webb *et al.* 2011a). The use of the term 'local' here is of course subjective and only reflects the variance in oxygen isotopes rather than any Nasca concept of community.

It is clear that the Nasca sphere encompassed a wide area. During the Early Nasca period obsidian for tools was transported from a wider variety of sources and from further away, compared to the Middle and Late Nasca (Eerkens *et al.* 2010). This suggests more trade and movement of goods, which is reflected by the presence of a small amount of Nasca pottery outside of the south coast (Goldstein 2000) and the occasional presence of spondylus in Nasca contexts (Silverman 2002: 158). This has been proposed to be indicative of elite interaction during the Early phase (Vaughn 2009).

Silverman (2002: 166) argues for Cahuachi as a location of a central cult that was a common unifier to a society that was regionally and socially segmented. The use of irrigation technologies along the length of the valleys to supply water to the intensively farmed fields would have necessitated co-operation between communities for canal maintenance and water distribution (Silverman 2002: 150). The idea that the early Nasca was not organised as a state

can also be taken from the lack of social differentiation in burial practices that shows there was no clear social hierarchy (Isla and Reindel 2006). At the local level each community had additional ceremonial foci but came together and interacted with other groups in Cahuachi. Others have described the Early and Middle Nasca social organisation as theocratic (DeLeonardis and Lau 2004), with the ceremonial site of Cahuachi at the heart of the culture.

Middle Nasca

Middle Nasca marked a transformation in the society. The decline of Cahuachi began in Phase 4, which is mirrored by a decrease in the number of habitation sites in the Ingenio, middle Grande and Palpa valleys, and the abandonment of some Nasca 3 sites altogether (Silverman 2002: 167). Other civic-ceremonial centres also were abandoned at the end of early Nasca, most notably Los Molinos in Palpa (Silverman 2002: 167). Evidence for intra- and inter-site differentiation is also lacking in Nasca 4 unlike in the preceding phases (Silverman 2002: 167; Silverman and Proulx 2002: 249). The break up is seen in the increased heterogeneity in the ceramic styles due to the decentralised influence of Cahuachi (Silverman and Proulx 2002: 250). The reason for the start of the collapse of the Nasca system is unclear. Silverman (2002) hypothesises that it is related to the differences in the communities that were only united by the ceremonial function of Cahuachi and the other civic-ceremonial sites. These differences became too large or one group chose to break the social norms causing a breakdown in the system. With the addition of a decline in water availability, these stresses may have proved too much for the Early Nasca system to cope with. The increased pressure on society is illustrated by the higher incidence of violent traumas, with examples of decapitation, parry fractures and obsidian points lodged into bones of individuals excavated (Cagigao 2009). Although these individuals are yet to be securely dated to Middle Nasca it can be taken as evidence that social tensions existed within the Nasca sphere.

Nasca 5 saw further disintegration of the old system. Cahuachi was used solely for burials and habitation sites were of varying size and configuration with no dominant site. Internal differentiation of sites was seen in both the architectural as well as civic-ceremonial features (Silverman 2002: 168). In the southern tributaries settlements shifted to the middle valleys due to better availability of water (Silverman 2002: 168). The continued drought has been blamed for the collapse in the Nasca society who resided in an environment sensitive to even small fluctuations in water availability (Eitel and Mächtle 2009). The use of filtration galleries allowed Nasca society to once again flourish in the southern tributaries (Cook and

Parrish 2005; Silverman 2002: 171). The now geographically restricted Nasca society was seen to be more competitive and socially divisive (Silverman 2002: 168; Silverman and Proulx 2002: 252) with each filtration gallery and its associated system defining a socio-political territory, which had a unique social identity (Silverman 2002: 150). The apparent competition in Nasca 5 for resources is most evident in the increase in trophy head taking seen during this phase. Oxygen and strontium isotopic analysis of Nasca trophy heads from all phases has indicated that the victims were members of 'local' populations (Buzon *et al.* 2011; Conlee *et al.* 2009; Knudson *et al.* 2009), revealing tensions and conflicts within the Nasca society itself.

Late Nasca

Many of the changes seen in the preceding phase continued during the Late Nasca period (Cook and Parrish 2005; Silverman and Proulx 2002: 260). Yet the sphere of Nasca influence expanded, with Nasca 7 seeing the widest area covered including populations in the highlands (Silverman and Proulx 2002: 261). The adverse environmental conditions that had begun in the Middle Nasca phase continued. Differences in settlement patterns can be seen between the different valleys, suggesting local responses to this continued decline in environmental conditions. Schreiber (1999) notes a change from small sites to fewer, larger sites in the middle valleys where water was more easily available.

This pattern has been interpreted in different ways. Silverman (2002: 171) argues for decentralisation of Nasca society, with the fragmentation and discontinuation of Early and Middle Nasca society. Schreiber (1999) suggests that Late Nasca society was now organised into a series of small political units, which were likely to come into conflict but could also be united over common values against some external threat. The resettlement pattern, which has also been observed for the Ica Valley, has alternatively been taken as a sign of greater centralisation (Cook and Parrish 2005). Along with the increasing complexity of Nasca ceramics (Silverman 2002), new elite burial practices also attest, in the view of Isla and Reindel (2006), to an increase in social and political complexity. They agree with Schreiber's interpretation of the presence of multiple political units in the valleys but instead believe that these units shared power and belonged to a state system with a clear social hierarchy.

Diet During the Nasca Period

The Nasca as a society reliant on agriculturalists is supported by a wide variety of evidence. Firstly, ceramic iconography depicts scenes of fishing and farming (Silverman and Proulx

2002: 135ff). Men are commonly portrayed as farmers and women are occasionally pictured making *chicha* (maize beer).

Excavations of Early Nasca sites in both the Río Nazca drainage and the Ica Valley have recorded a suite of domesticated plants including maize, beans (*Phaseolus* spp. and *Canavalis plagiosperma*), sweet potato (*Ipomoea batatas*), manioc, jíquima, chilli (*Capsicum* sp.), squashes (*Cucurbita sp.*, *Lageneria siceraria*), achira (*Canna edulis*) and peanut as well as a number of fruits such as pacay and guava (*Psidium guajava*) (Beresford-Jones *et al.* 2011b; Piacenza 2005; Silverman 1993; Valdez 1994). Wild foods, such as chenopods, amaranths and huaranga (Beresford-Jones *et al.* 2011b; Piacenza 2005) have been recovered in addition to these, prompting Beresford-Jones *et al.* (2011b) to suggest that wild resources were still exploited as an important supplement to the diet. Notably coca and potatoes were largely absent from these Nasca sites suggesting they were not of great importance (Piacenza 2005) or that the production zones they were grown in were not part of any ecological complementarity system that was in use at the time.

Midden material from Late Nasca contexts suggests continued and intensified farming, resulting in an increase in the salinity of the soil, as indicated by an increase of the weed *Sesuvium portulacastrum* (Beresford-Jones *et al.* 2011b). In several other sites analysed for botanical remains the same suite of domesticated plants is usually observed. As well as agricultural products, cotton was also a major crop grown by the Nasca. It was used in textiles as well as fishing nets and could have been grown throughout the south coast region (Silverman 2002: 152). Direct dietary evidence from isotopic studies support the notion that the Nasca had an agriculturally based diet with no significant contribution from marine resources (Horn *et al.* 2009; Kellner and Schoeninger 2008; Webb *et al.* 2011b).

Llamas were an important part of Nasca life, suggested by depictions on ceramics involving aspects of llama herding (Silverman 2002: 151). Isotope work on camelid remains from the south coast indicates that camelid populations were resident at archaeological sites on the coast (Horn *et al.* 2009). As well as a source of meat, llamas also may have dung for the manuring of agricultural fields (Horn *et al.* 2009). Adult camelid remains at Cahuachi suggest that domestic herds were sacrificed there before being consumed in feasts during Early Nasca times (Valdez 1994). Late Nasca ceramics depict llama herders as well as coca chewers (Silverman and Proulx 2002: 135), which suggest the presence of long distance movement of goods via caravans for highland goods such as coca, despite the lack of evidence for this

plant in archaeobotanical assemblages. Ceramics also depict camelids being hunted with obsidian-tipped spears, which have been interpreted as guanaco hunting in the *lomas* (Silverman 2002: 152). Ancient DNA analysis of camelid remains from the Palpa region supports the evidence for both llama and guanaco as food sources, whereas wool from alpacas and vicuñas was primarily imported from the highlands (Renneberg *et al.* 2009). Silverman (2002: 152) also reports several incidences of guinea pig remains or excrement in a number of sites, suggesting that these animals contributed to Nasca diets.

Comparatively low rates of the pathological condition cribra orbitalia have been observed for Early and Middle Nasca populations (Cagigao 2009). This pathology has a complex aetiology and is thought to be associated with dietary deficiencies of iron or essential vitamin B_{12} (Aufderheide and Rodríguez-Martín 1998; Ortner and Putschar 1981; Walker *et al.* 2009). Often increased rates of cribra orbitalia are linked to a high maize diet, which is a nutritionally poor plant, but this does not seem to be the case in the Palpa area, raising questions about the reliance on maize during the Nasca period. Yet the mortality profile observed for the Nasca populations is as expected for an agriculturally reliant population (Cagigao 2009). Palaeodemographic work, on the other hand, on Early and Middle Nasca populations from the Nasca Valley has shown the health status and death rates to be in agreement with those expected for an agriculturally based society (Cagigao 2009; Drusini *et al.* 2001).

Summary

The Early Nasca were a centralised society with social differentiation, organised agriculture and the ability to move goods across the south coast region. With the apparent decline in water availability in Middle Nasca times, society fragmented and became unstable with increasing conflicts evident. However, these pressures abated somewhat in the Late Nasca. The continued drought is thought to have elicited local adaptation that created differences within the valleys and within the populations. The social complexity associated with the Late Nasca period is evident in the increasing complexity in the iconography. It is not seen universally in isotopic analyses of palaeodiet, though , perhaps indicative of the different mechanisms employed by the valleys in response to the changing environmental conditions. Fishing, farming and llama herding and caravans seem to be important throughout the Early Intermediate Period but evidence also points to the use of wild plants as a potentially important aspect of Nasca diet.

2.4.3 Middle Horizon

The Middle Horizon is characterised by the emergence of two highlands societies - the Wari empire to the north and Tiwanaku to the south - both of which expanded and dominated a wide area of the Andes. This sees a change from the previous two periods, as the dominant culture developed from outside the south coast region.

The Wari 'Empire'

Wari society was centred around the site of the same name, near modern day Ayacucho, in the highlands of Peru (see Figure 2.3). Its territory stretched as far north as Cajamarca in the highlands and Lambayeque on the coast, and as far south as the Department of Cuzco in the highlands and the Moquega valley on the coast where it formed a frontier with the Tiwanaku culture that dominated the southern part of Andes centred at Lake Titicaca (Schreiber 1992: 94). Radiocarbon dates from the Palpa-Nasca region date the Middle Horizon to 630 to 820 A.D (Unkel and Kromer 2009), although in the highlands it continued until c. 1000 A.D.

Wari material culture is somewhat derivative of the Nasca, with many similarities between their ceramic styles and iconography (Cook 2004; Menzel 1964; Schreiber 1992). The extent to which the Wari and Nasca are related is still unclear, although new evidence points to Late Nasca society extending much further into the Ayacucho highlands than previously thought (K. Schreiber *pers. comm.*). A strong link existed between the Wari and the Huarpa culture, forebears to the Wari in the Ayacucho highlands, in terms of ceramic style although the Huarpa also has stylistic elements pertaining to Nasca 7 (Schreiber 1992: 83). The Huarpa area of the heartland is used as an indication of the initial Wari heartland and covers some 750 square kilometres in the drainage region of the Río Cachi (Schreiber 1992: 84).

Wari became the dominant site in Middle Horizon 1 and is termed a city at this point by Schreiber (1992: 87). It continued to grow in size and the immediate surrounding area became less occupied as the population concentrated in the capital in Middle Horizon 2 (Schreiber 1992: 90). Its expansion was rapid - taking only two or three generations - and it endured for several hundred years further until approximately 1000 A.D. (Cook 2004; Schreiber 1992: 267).

The Wari are described as an empire incorporating a diverse mix of ethnic groups and ecological zones in which a variety of political strategies were developed, suited to the local conditions (Schreiber 1992: 266). Numerous Wari centres are known away from the heartland but only in the highlands. Administrative centres were built in order to maintain

control and collect taxes or tribute payments (Schreiber 1992: 89), which were used to reinforce rule and dictate social and economic changes (Topic 1991).

The Wari Coastal Hinterlands

The remnant Nasca populations are described as "Wari-ized" (Silverman and Proulx 2002: 270), as their neighbours from the highlands became more influential and incorporated the local populations into their tribute system. It has not been fully established whether the Wari conquered the south coast or strongly influenced it (Conlee 2010; Schreiber 1992: 107; Silverman and Proulx 2002: 272). DNA evidence suggests that there was no population change or significant migration from the highlands (Fehren-Schmitz *et al.* 2009), yet in the Río Grande drainage rectangular compounds have been identified as possible administrative centres due to their similarity to highland administrative centres (Schreiber 1992). However the fact that there are only a limited number of possible administrative sites suggests that direct political control of the area was not implemented unlike in the highlands (Conlee 2010; Schreiber 1992: 271; Topic 1991). Recent isotopic studies have attempted to address the issue of the possible presence of resident elites on the coast. Three sites, Ancón, La Tiza and Pajonal Alto, have all yielded 'non-local' individuals (Conlee *et al.* 2009; Slovak and Paytan 2011). Whilst it is not certain where these individuals originated from, the highlands around Ayacucho or Cuzco have been put forward. These individuals are taken as support for the presence of Wari highland elites on the coast, yet this is not observed universally. In the site of Beringa, at the southern end of the Wari empire, the same type of analyses has yielded negative results in terms of incomers from the highlands (Knudson and Tung 2011).

Other significant differences within the Wari presence on the south coast have also been noted (Conlee 2010; Silverman and Proulx 2002: 273). In the lower parts of the Ica and northern Nasca drainage valleys (Santa Cruz, Grande, Palpa and Ingenio) virtually no Middle Horizon settlements have been recorded. This is a curious fact in itself as midden material has been recorded as well as numerous cemeteries (Beresford-Jones *et al.* 2011a; Reindel and Isla 1998 cited in Conlee 2010; Silverman 2002; Proulx 1999 cited in Silverman and Proulx 2002). Cook (1992) has alluded to the presence of elite residential sites in the lower Ica Valley and archaeobotanical material from Casa Viejo in Callango has been published attesting to occupation in the early part of the Middle Horizon (Cook and Parrish 2005; Roque *et al.* 2003), although nothing further has been published. In the southernmost valleys of the Nazca drainage (Nazca, Taruga and Las Trancas) there is evidence of Wari occupation in the middle basins (Conlee 2010). The size of sites, such as La Tiza in the Nazca Valley and

Pajonal Alto in the Taruga Valley, were much smaller in the Middle Horizon than their occupation during the Early Intermediate Period and Late Intermediate Period (Conlee 2010). This, and the lack of archaeology sites in the lower valleys, is perhaps a reflection on the difficulty in occupying this area due to the continuing severity of the drought which has been proposed as beginning in the Early Intermediate Period and did not end until the 14th century (Eitel and Mächtle 2009).

Religion appears to have had an important role in the expansion of Wari on the south coast, visible in the widespread ceramic tradition and in architecture. The widespread use of multiple burials in rectangular tombs is also an indication of the spread of an ideological belief stemming from the Wari (Conlee 2010). At sites such as La Tiza and Pajonal Alto rich Wari-type graves are seen alongside local burial practices, illustrating that there was not a complete replacement of regional practices (Conlee 2010). Funerary treatment of males and females in the Middle Horizon is considered to be different in the Palpa region, due to the absence of any male in the burials excavated (Cagigao 2009), although the sample number was only 17.

A number of sites on the coast and in the highlands also record the presence of trophy heads. This practice was continued from the Nasca period. All ages and genders were represented by trophy taking. Of 18 buried at Conchopata in the highlands it was found that 14 were not 'local' in terms of strontium isotope values (Tung and Knudson 2011). Given the presence of infants in the trophy head sample, village raids (as opposed to battles) would have been the likely source for victims. This has been taken as evidence for the use of militaristic tactics in order to subjugate the conquered populations by means of reinforcing power and rule through rituals involving human sacrifice (Tung and Knudson 2011). Similar results were found in the Nasca drainage with 'non-local' (in the sense of strontium isotopes) trophy heads present alongside 'local' ones (Conlee *et al.* 2009), supporting Tung and Knudson's (2011) argument.

Isotopic palaeodietary results have suggested that maize was not being intensively farmed nor used to reward certain sectors of the population for complying with Wari control, and thus agricultural management was not being conducted by the Wari (Kellner and Schoeninger 2008). This is contrary to the type of imperial rule used by the Inca empire in the highlands during the Late Horizon (Hastorf 1991) and therefore suggests a less direct type of governance used by the Wari. The absence of state intervention in resource management is also evident in the fact that the same obsidian sources that were utilised by the south coast

populations in both the Early Intermediate Period and Middle Horizon (Eerkens *et al.* 2010). Kellner and Schoeninger (2008) proposed that the Wari were present on the south coast in order to extract cotton as tribute payment from the local populations. This cotton was vital for the numerous textiles made in this period. Similarly cotton was the most abundant plant remain found in the excavations at Casa Vieja in the Callango basin (Roque *et al.* 2003) and hugely abundant in mortuary contexts from the Samaca basin (Beresford-Jones 2011; Beresford-Jones *et al.* 2011b), both in the Ica Valley.

Finally, Middle Horizon sites were abandoned in the south coast region after Middle Horizon 2, at the end of the 9th century A.D., yet the Middle Horizon continued in the highlands until c. 1000 A.D (Conlee 2010; Unkel and Kromer 2009). On the south coast there was not an immediate replacement of the Middle Horizon sites, with an apparent hiatus of occupation for around 300 years (Conlee 2010; Unkel and Kromer 2009).

Diet During the Middle Horizon

Isotopic analyses of human and faunal samples from sites close to the Wari centre, including the site of Wari itself, have been used to argue that the human diet was composed primarily of maize (Finucane 2009; Finucane *et al.* 2006). There was no dietary difference between the sexes, suggesting that specific foods were not reserved for certain social sectors. Of course this does not rule out that different types of preparation of the same food were associated with specific social groups, e.g. the consumption of maize as *chicha* or as a cob. Two different animal husbandry strategies were thought to be in use in highland sites (Finucane 2009; Finucane *et al.* 2006). Camelids were either pastured on the *puna* or corralled in the urban centres and foddered on maize (Finucane *et al.* 2006). These differences in foddering techniques are interpreted as a reflection on the different species in each group, with alpacas being kept in the *puma* and used as a source of wool, whereas llamas were kept near urban areas, foddered on maize and used for caravans.

In the hinterlands at the coastal site of Ancón, near the modern day city of Lima (see Figure 2.3) isotopic studies have been used to argue that the population ate a considerable amount of marine foods, although this was gradually replaced by a maize based diet over the course of the Middle Horizon (Slovak and Paytan 2011; Slovak *et al.* 2009).

Further inland, the populations from the Las Trancas Valley had a varied agriculturally-based diet (Kellner and Schoeninger 2008). Dietary breadth increased in the Middle Horizon from earlier times both in terms of types of plants and amounts of meat consumed, suggesting a

differential access to resources, although not significantly associated with any particular group. Further evidence for agriculturally-based diets is seen in the archaeobotanical record at Casa Vieja in the Callango basin of the Ica Valley (Figure 2.5). Early Middle Horizon deposits have a high proportion of maize and huaranga, alongside smaller numbers of the main other domesticates (beans, squash, potato, manioc, fruits etc) as well as wild food species such as sedges (Cook and Parrish 2005; Roque *et al.* 2003). Cook and Parrish (2005) argue that the levels of maize, beans and squashes in the flotation remains fluctuate slightly over time but not enough to suggest that the ability to grow them was adversely affected by any droughts or climatic changes. This is in contrast to the settlement data that Conlee (2010) uses to suggest that the environment was too degraded for habitation in the lower valleys, and perhaps indicates local differences in the environment. An agricultural subsistence base is also reflected in the mortality profiles for the individuals buried in the Palpa region, which is a U-shape distribution typical of agricultural populations (Cagigao 2009).

A different scenario is seen in the lower Ica Valley, with a virtual absence of domesticated plants in middens with the exception of cotton. Wild plants dominate the archaeobotanical assemblage suggesting such a severe decline in the fertility of the land after the extensive exploitation of the Nasca that the Middle Horizon populations here had led to return to a hunter-gatherer style of subsistence (Beresford-Jones *et al.* 2011b). An abundance of marine shellfish is also observed in these deposits suggesting their importance in the diet (Beresford-Jones *et al.* 2011b) contrary to what is seen in the sites in the middle parts of the valleys on the south coast.

Finally, the levels of pathology observed in Palpa populations suggest a decline in health in the Middle Horizon. The rates of cribra orbitalia seen in the Middle Horizon were comparable to the high level of the Paracas period, and much higher than those of the Nasca period (Cagigao 2009). The cause of cribra orbitalia has been frequently linked to iron-deficiency anaemia but Walker *et al.* (2009) argue that, whilst dietary-deficiencies are clearly linked to this condition, it is a combination of poor nutrition, poor sanitation, infectious diseases and cultural practices that is responsible for the high levels generally seen in the archaeological record. Therefore this clear decline in health shows that some sort of change had occurred, although the nature of it is uncertain.

Summary

The nature of the highland-based Wari empire on the south coast is somewhat unclear. Evidence from various sites across the region does not universally agree on the presence of elites or 'outsiders' from other areas of the empire. However, the Wari empire appears to have used a variety of strategies to suit the local population and environment, which may result in the differences observed. With the continuing drought this would be a reasonable suggestion given the responses elicited in the Late Nasca period. Differences in the south coast populations are already seen in the varied dietary data from numerous valleys. There is evidence for trade or movement of goods between the coast and the highlands. It is unclear why the Wari chose to bury individuals in basins where they did not appear to live, such as Samaca and Ullujaya.

2.4.4 Late Intermediate Period

In the south coast a hiatus between Middle Horizon occupation and the Late Intermediate Period has been shown with radiocarbon dates from several sites. Occupation became very scarce during the 9th century A.D. and restarted from approximately 1200 A.D. (Conlee 2010; Unkel and Kromer 2009), coinciding roughly with the end of the evidence for the drought that apparently plagued the late Early Intermediate Period and Middle Horizon (Eitel and Mächtle 2009). The change was dramatic compared with what was seen in the preceding epochs - monumental architecture ceased, the number of local elites increased, there was a diversity in settlement type, economic organisation changed and iconography and burial practices changed (Conlee 2003, 2010).

On the south coast, it has been observed that, whilst some cultural attributes were shared throughout the different valleys, each one is likely to have acted like an independent political entity (Conlee 2003). Historical sources, albeit those written centuries after the event, lend support to this hypothesis as they document that at the time of the Inca invasion, c.1440 A.D., the Cañete, Chincha and Ica Valleys all had different rulers (Menzel 1959). Pottery styles certainly were shared among the valleys, although each had its own centre of influence. Menzel (1959) names four different pottery styles, from north to south as Chincha, Ica, Poroma and Acarí. There is a certain amount of overlap between the artefacts and archaeological features in each of the valleys, which prompted Menzel (1976: 234) to argue that they belonged to the same community and had a shared identity. Subsequent archaeological investigations have yielded evidence that makes some differences more

apparent, but ideas of community and identity are complex and the degree to which these were present in intra- or inter-valley settings is still unknown.

The ability to answer such questions about the Ica Valley is hindered by the sparse work carried out on Late Intermediate Period remains from the valley. The majority of the other south coast valleys have been investigated to a greater extent, a fact obvious from review articles, such as Covey's (2008:24ff) which reference no data directly gathered from the Ica Valley. As a result of this lack of work, the Ica Valley is often lumped together with the valleys to the north in terms of settlement patterns which saw sites located in indefensible locations on the floodplains or near the coast (Covey 2008). From the survey of the Samaca and Ullujaya basins this also appears to be true for the lower Ica Valley (Beresford-Jones 2011; Beresford-Jones *et al.* 2011a). The main administrative centre and capital of the Ica Valley, encompassing both domestic and burial areas, was Ica Vieja located approximately 10km south of the modern day city of Ica (Menzel 1959, 1976: 12). Evidence from tombs excavated at Ica Vieja shows marked social differentiation in terms of grave goods, for example some contained gold and silver ornaments (Menzel 1976: 224). Several other smaller sites have been recorded for the middle and lower valley (Menzel 1976: 17), including domestic or specialised processing sites and cemeteries in Samaca (Beresford-Jones 2011; Beresford-Jones *et al.* 2011a). This period also witnessed extensive cultivation of the middle valley, due to the expansion of the Achirana canal from the upper valley into middle valley (Massey 1991).

Due to the lack of data from the Ica Valley, inferences about the possible structure of Late Intermediate Period society will have to be drawn from the other south coast valleys. However there are clear differences between the valleys to the north and those to the south.

The valleys to the south of Ica are described as "balkanised states" by Covey (2008: 24ff). This can be seen in the case of the northern part of the Nazca drainage, where sites agglutinate and population increases, but in defensible locations, contrary to the exposed location of sites in the Ica and Chincha Valleys. Conlee (2003) thinks this is due to their proximity to the Ica Valley and a threat posed by their more centralised neighbours. Yet elements of the Ica ceramic style have been found in ceramics from the Nazca Valley, which are predominately of the Poroma style (Conlee 2003; Menzel 1959) suggests that there was a certain amount of amicable interaction. In the southern part of the drainage site hierarchy based on size is evident, with La Tiza the most prominent (Conlee 2003). The presence of

elites at this site has been inferred from the unequal spatial distribution of foodstuffs at the site, which suggests differential access, as well as Ica fineware ceramics present in certain contexts. Elites were thought to have been involved in regional scale trading of cotton, ceramics and perhaps marine resources out of the coastal valleys for camelid products and high altitude crops from the sierra (Conlee 2003).

Evidence for travel outside of the immediate south coast region is also found in source analysis of obsidian tools, which indicates that sources other than the closest were exploited (Eerkens *et al.* 2010), as well as the presence of both domestic and wild camelids including alpacas and vicuñas (Renneberg *et al.* 2009). Contact with the highlands was not necessarily carried out to the same degree everywhere as the abundance of cotton but lack of camelid fibres at Pajonal Alto has been taken as evidence for only limited interaction (Conlee 2003). Clay sourcing of ceramics from Pajonal Alto also indicate a variety of sources were used, indicating a decentralisation of ceramic production and movement of goods between settlements within the region (Vaughn *et al.* 2006).

To the north, the Chincha Valley was the largest centralised polity of the south coast continuing in importance into the Late Horizon and up to the Spanish Conquest. The nature of the centralisation in the Chincha Valley is thought to be political as well as religious, with the capital, La Centinela, situated near the coast containing pyramids and multiple compounds (Morris and Santillana 2007: 138). The Chincha were economically powerful with numerous fishers, farmers and long distance llama caravan traders who are thought to have linked the coast as far as Ecuador to the southern highlands (Rostworowski 1977; Uhle 1924: 59). Investigations into the Late Intermediate Period in the Chincha Valley remain quite limited although sites have been recorded in the middle and upper valley (Morris and Santillana 2007: 136) suggestive of the trade networks proposed by Rostworowski (1977).

Menzel (1959) suggested, albeit based on limited archaeological evidence, that the Ica Valley was centralised like the Chincha Valley although possibly only in a religious sense. This is perhaps because of the wide ranging influence of the Ica ceramic style, especially in Pisco and Huayurí.

Dietary Evidence on the South Coast

Dietary evidence from the south coast is sparse for this period. The importance of fishing can be clearly seen in the Chincha data and similar subsistence techniques are thought to have been used all along the south coast of Peru (Rostworowski 1977: 122). The employment of

irrigation agriculture is also a clear feature of the Ica Valley with the construction of the Achirana canal as well as floodplain agriculture using small sunken fields, as seen in the Callango basin (Massey 1991). In the upper reaches of the valleys water harvesting techniques were employed to catch run-off to use for agriculture (Eitel and Mächtle 2009). At La Tiza in the southern part of the region, purple corn, yucca and coca were all recovered (Conlee 2003) - the latter plant attesting to exchange between the coast and higher altitudes. Meat featured in the diet of the populations with burnt and cut camelid remains located in a feasting context at La Tiza and shellfish remains were also common and thought to have been traded into Pajonal Alto (Conlee 2003). Cotton was also a common material on coastal sites and most probably grown locally (Conlee 2003).

Summary

In summary, the Late Intermediate Period is characterised by regional development that was roughly divided by valley. The Ica Valley was likely to have been centralised like the Chincha Valley, although perhaps to a lesser degree. Social differentiation is clearly seen in Ica Vieja. Improved environmental conditions saw agricultural productivity increase. Fishing and long distance trade with the highlands seemed to be a key economic strategy along with farming. However, the understanding of the Ica Valley during this period is limited and thus this research aims to test whether the Ica Valley was similar to the Chincha Valley to the north or the valleys to the south.

2.5 Archaeological Background Summary

The four periods studied in this research can be summarised as thus:

The Late Ocucaje phase of the Early Horizon is a time of cultural and probable economic transition. This research aims to test the extent to which wild and domesticated resources are important in the diet of this population. Focus will then turn to whether by understanding the dietary strategies of the population it is possible to gain a greater understanding of the place of the Samaca populations in the wider Late Ocucaje socio-political changes that were occurring in the lower Ica Valley at the time.

The Late Nasca phase of the Early Intermediate Period is thought to be a time of socio-political decentralisation occurring during environmental instability. The dietary strategy of the Late Nasca population is hypothesised here to be one reliant on domesticates but the

environmental and social pressures created differentiation within the strategies. The dietary signal of the population studied in this research will be compared to those seen in other south coast populations in order to look at issues of decentralisation of Nasca society.

The Middle Horizon highland Wari empire had influence over the south coast populations but the extent to which they maintained a presence there is uncertain. A continued decline in the environment has been proposed by some as occurring, thus making the south coast an unattractive place to live in terms of resources available. In this research I first look at what the subsistence regime of the lower Ica Valley populations was during this period and whether agriculture was used. Following this I examine the nature and interests of the highland Wari empire on the south coast and what evidence there is for a resident elite population.

Finally, the Ica-Chincha polity of the Late Intermediate Period is largely unknown. This period of regional development saw the emergence of the powerful Chincha polity to the north but the southern valleys of the south coast were home only to smaller, less centralised societies. This research studies the lower Ica Valley population with these neighbouring societies in mind, examining the extent to which the Ica Valley is centralised like Chincha as has been proposed in the literature. By analysing the diet of the lower Ica Valley population the relationship within the population and between the lower valley and other areas can be assessed, informing on the economic basis of the valley and thus providing a comparison to the other valleys.

Chapter 3 The Archaeology of the Lower Ica Valley and the Sites Used in this Research

The area chosen for this research is the lower Ica Valley, specifically the Samaca and Ullujaya basins (see Figure 2.5). This area benefits from the existence of recent archaeobotanical research, creating a platform on which this research is based. The lower Ica Valley is also removed from the area of the south coast that has been most intensively studied (the Río Grande de Nazca drainage) and thus provides a new archaeological perspective, helping to refine our understanding of the south coast as a whole. This chapter shall being with a brief overview of the archaeology specific to the Samaca and Ullujaya basins and the known funerary information.

The second half of this chapter describes, in chronological order, the looted cemeteries in Samaca and Ullujaya that provided accessible material for this research. Even those these cemeteries have been looted it has been possible to salvage information from the otherwise denuded contexts. These cemeteries were identified and located with the assistance of Arnaldo Galindo, who as a boy accompanied his father, Seferino Galindo, the most famous *huaquero* (looter) from this region, when he looted the cemeteries. Since the late 1990s, the cemeteries in Samaca have not been looted thanks to the protection of the land owner, Alberto Benavides. The cemeteries in Ullujaya have unfortunately been further destroyed in recent years.

Fieldwork permits granted by the then Instituto Nacional de Cultura del Perú (now renamed Ministerio de Cultura del Perú), allowed surface collection of looted human and animal remains for isotopic analysis from seven cemeteries. Full details of the fieldwork have been produced in a report submitted to the Ministerio de Cultura (Cadwallader and Arce Torres 2012).

3.1 The Archaeology of the Lower Ica Valley

Although several surveys of the lower Ica Valley have been carried out (Beresford-Jones *et al.* 2011a; Cook 1991; Massey 1986) there has been relatively little excavation of sites, nor have these surveys been amalgamated. An amalgamation of the data would be problematic, in part due to the differing precisions of the survey techniques, which is compounded by the

modern destruction of sites that appear on the earlier surveys (see Beresford-Jones 2005: 251ff for discussion on this).

A number of archaeological sites have been surveyed in but the majority of these appear to be remnants of sites or middens as opposed to settlements. These sites have been subjected to very limited archaeological research and have been severely degraded by large scale deflation by the wind. Survey of parts of the Samaca basin have revealed a range of features, such as relict canals, cemeteries, terraces, mounds and enclosures, although these are often not securely dated (Beresford-Jones 2005). The limited excavation has revealed an early Ocucaje midden (c.750 B.C.) beneath Nasca field systems in Ullujaya (Beresford-Jones 2011), indicating that this area was inhabited during both periods. Various other relict canal courses believed to date to the Early Intermediate Period run across both Samaca and Ullujaya but an associated settlement has yet to be found (Beresford-Jones 2005). No Middle Horizon settlements have been identified in the basins, yet both cemeteries and middens are present in Ullujaya. As discussed in Chapter 2, there are Middle Horizon settlements in Callango (Cook 1991), which may explain the lack of settlements in Samaca and Ullujaya. Finally, a large and well preserved Late Intermediate Period settlement is clearly evident in Samaca but no excavations of sites dating to this period have been carried out.

The scant settlement pattern information available for the Samaca and Ullujaya basins shows that the basins themselves were mainly used during the Early Intermediate Period and Middle Horizon, especially in Ullujaya (Figure 3.1). Prior to this in the Early Horizon, there are too few sites to make strong conclusions about their use of the basins. The Late Intermediate Period sees more and larger sites in the Samaca basin.

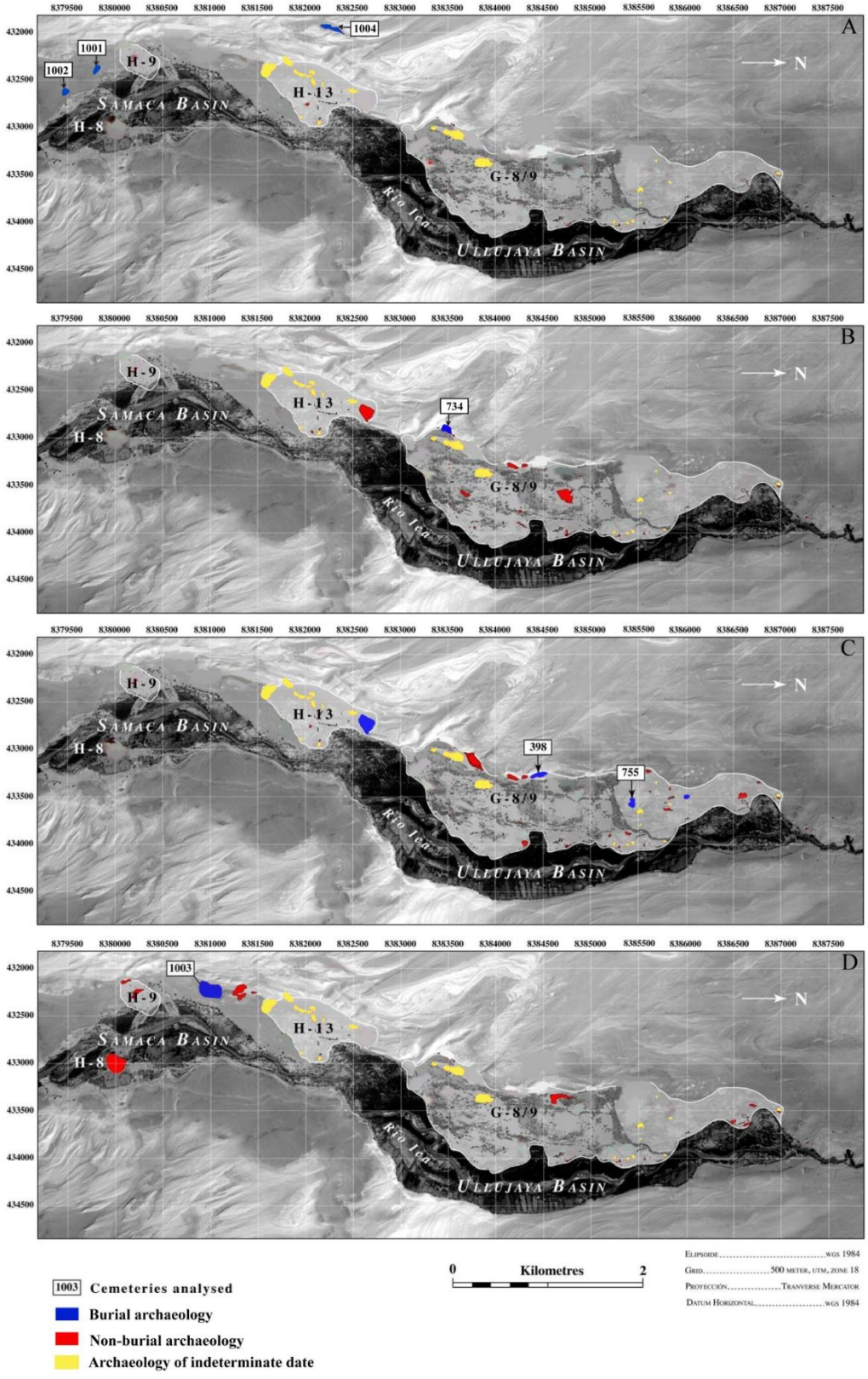

Figure 3.1. Known sites (coloured red and blue) in the Samaca and Ullujaya basins dating to each period studied in this research. From top to bottom: A: Early Horizon, B: late phases of the Early Intermediate Period; C: Middle Horizon; D: Late Intermediate Period. Non-burial archaeology includes habitation sites, canals and middens. Image courtesy of Dr Beresford-Jones.

Little is known directly about the burial archaeology of the lower Ica Valley, although funerary contexts have been studied in the other south coast valleys. Although many funerary contexts have been excavated or recovered from looted sites, such as the work by Tello and Mejía in Paracas and Las Trancas (1967, 1979), there are actually very few systematic scientific studies of them. The largest and best studied originate from the Palpa region (Isla 2009). Briefly, the typical funerary context observed in Palpa (Isla 2009) that is relevant to this thesis can be summarised as follows:

Early Horizon (late Ocucaje phases): Individual pit burials, body in dorsal position with legs extended or flexed. The body may be wrapped in plain cloth. Stones or adobes were placed on or around the bodies. Funerary urns were used for infants who were placed in a seated position. Grave goods included ceramics, worked obsidian and stone, beads and cotton cloth.

Early Intermediate Period (late Nasca phases): Burials were either in the form of individual pits or *barbacoas*. Pits were circular or oval, with a diameter of 0.5-1.2m and a depth of 1.5-2m. The entrance was often lined with stones and the pit sealed with a layer of mud. Roofs were occasionally made with canes or huarango beams. *Barbacoas* were oval or quadrangle shaped chambers, 1.5-2m long with a depth of 1.5-3m. Adobe or stone walls were common. A solid roof of huarango beams, tied canes, pacay leaves and stones was built which was sealed with mud. Bodies were interred in either an extended dorsal position, with flexed legs, or in a seated position with knees at the chest and the arms either between the knees and chest or wrapped around the legs. Grave goods included plain cloth, ceramics, and vegetable and faunal remains.

Middle Horizon: Three types of graves were used in this period. These were 1) simple or uncovered pits - individual burials in circular or oval pits usually covered with mud. Bodies were in a seated position with arms around their legs. Due to poor preservation, only ceramics were recovered in this type. 2) Roofed pits - similar to the simple pits but with a roof of large slabs or *barbacoa* type roof. These were single burials with the body in a flexed or semi-flexed position, accompanied by ceramics, beads and spondylus. 3) Multiple individuals in a chamber - these were quadrangle shaped, 2x2m long and 1.5-2m deep, often with a stone wall protruding up above the ground level marking the tomb. They were roofed with huarango beams, mud and stones. At least two individuals were interred along with ceramics, spindle whorls, beads, copper, semi-precious stone beads and obsidian tools.

Late Intermediate Period burial archaeology was no included in the study by Isla (2009).

3.2 The Cemeteries of the Lower Ica Valley

The cemeteries selected for sampling were chosen based on the amount of useable material on the surface of each cemetery. Where the amount of material was low, multiple cemeteries were sampled. Each cemetery is identified by a number. Ceramics were collected in order to date the cemeteries using well established chronologies for the region (Menzel *et al.* 1964; Silverman 1993; Silverman and Proulx 2002).

3.2.1 The Early Horizon Cemeteries

Three cemeteries were selected from the Late Ocucaje phase of this time period in order to have a meaningful sample size. All were located in the Samaca basin – two on the margins of the valley floor (Cemeteries 1001 and 1002) and the other (Cemetery 1004) further up in the hills flanking the Tablazo de Ica.

Cemetery 1001

Cemetery 1001 is located at the southern end of the Samaca Basin, on the edge of the level just above the basin. From the northern edge of the cemetery the valley opens up (Figure 3.2) and the river continues past the eastern edge as it enters the canyon and carries on southward. To the south of the cemetery the desert expands towards the Lomas de Aymara.

In total the cemetery is approximately 140m from east to west and approximately 28m north to south at its widest point. It has been divided into 2 sectors - A and B based on the distribution of *huaquero* (looter) activity (Figure 3.3). Sector A is the area with the more concentrated looting activity and from which all of the samples were taken. Sector B is the western half of the cemetery and has a much lower concentration of disturbance. Given the depth of the *huaquero* pits and their infilling of wind-blown deposits it is evident that this cemetery has not been looted in recent times. Only one tomb structures, a circular pit, was observed (Figure 3.4).

Figure 3.2 Cemetery 1001, looking north-northeast. Photograph by author.

There are incidences of bone that have obviously been on the surface for some time. These are extremely degraded due to the sun and wind and it was often impossible to identify them as either human or animal. In cases where the bone was only partly exposed, the covered part was often of a much better condition and would show little signs of sun and wind damage. Human remains were often found near fragments of ceramics and shellfish. In comparison to the majority of the other cemeteries the number of both humans and animal remains was sparse.

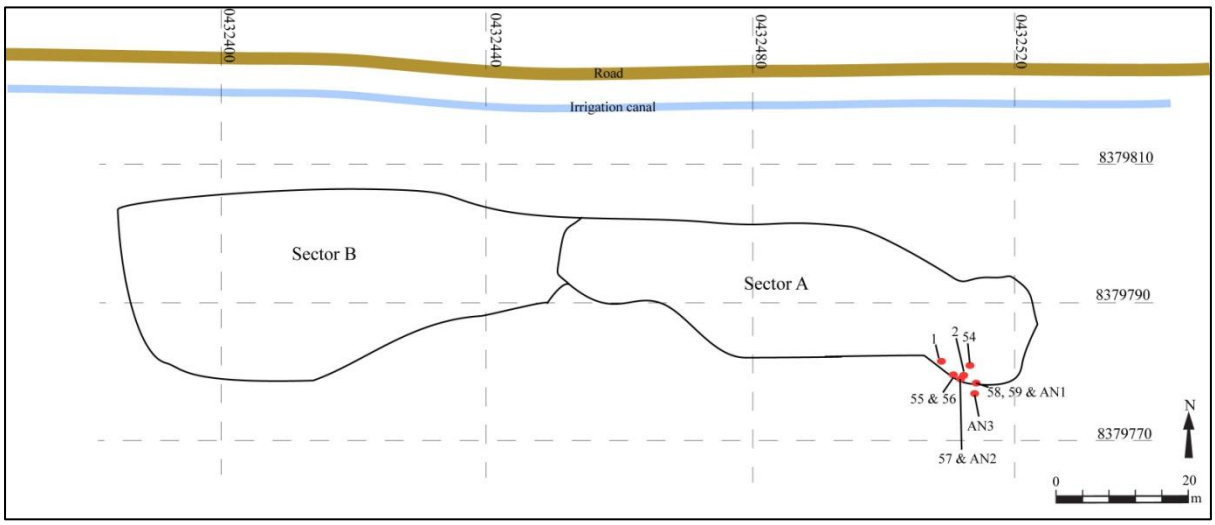

Figure 3.3 Plan of Cemetery 1001 showing location of samples taken. The red circles indicate the location of the human samples (identified by a number) and faunal samples (identified by 'AN' followed by a number) taken. Plan drawn by author.

Archaeological material was spread across the whole cemetery and did not differ in the two sectors. A scant number of ceramics were present on the surface of the cemetery. The majority of these were fragments of plain domestic ware. These did include distinctive rims, collars and handles (Figure 3.4). One example of negative painted pottery was also recovered. Those that are diagnostic date to Ocucaje Phases 9 and 10. Desiccated plant remains were very occasionally recovered whilst removing partially buried bones for analysis and sampling. These include a maize husk, maize cobs and reeds.

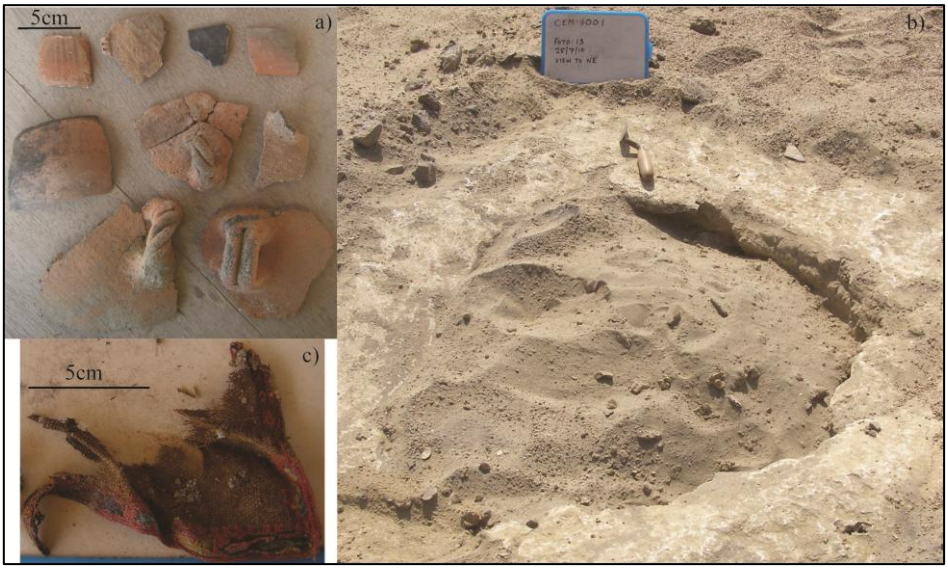

Figure 3.4 Cemetery 1001 material culture and archaeological feature. Clockwise from top left: a) diagnostic ceramics (Ocucaje Phases 9 and 10); b) cut of a tomb in Sector A; c) fragment of textile with Late Ocucaje style design. Photograph by author.

Cemetery 1002

Cemetery 1002 is located very close to Cemetery 1001 (see Figure 3.1) and shares the same position within the valley with respect to the major landmarks. The extent of the *huaquero* activities is used to define the shape of the cemetery as a rounded triangle shape (Figure 3.5). The longest dimension of cemetery is on a NW-SE access and is approximately 85m. The NE-SW dimension through the mid-section of the cemetery is approximately 51m. This cemetery has not been divided into sectors as there is no difference in archaeological material observed in terms of both chronology and distribution.

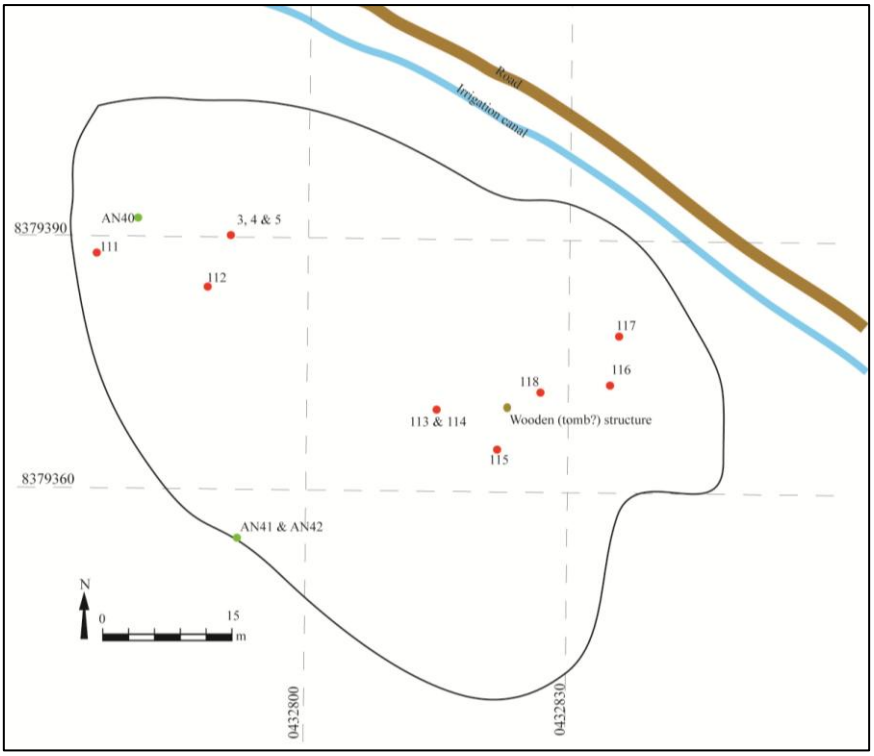

Figure 3.5 Plan of Cemetery 1002 showing location of samples taken. The red circles indicate the location of the human samples and the green circles represent the faunal samples. Plan drawn by author.

Like Cemetery 1001 the looting activity does not appear to have been recent. However, part of the cemetery, chiefly the northeast end, has seen heavy disturbance – much more so than in Cemetery 1001. In one area in particular there is heavy disturbance around what appears to have been a tomb with four wooden posts arranged in a square, with sides of 65cm (Figure 3.6). This is the only *in situ* evidence of wooden structures although there are pieces of huarango wood (c. 70cm long with a diameter of 5cm) on the surface of the cemetery that may have formed tomb structures.

Like the previous cemetery there was very badly degraded bone, both human and faunal, present on the surface and partially buried remains offered much better preservation. No useable human crania were found, with only a few fragments of very badly degraded cranial elements observed. Camelid bones were present on the surface.

Figure 3.6 Pits dug by the looters and the wooden structure observed in 1002. Photograph by author.

Mainly fragments of plain domestic ware were found on the surface. Ceramic fragments with incised lines, described as *ralladores* (literally translated as "graters"), were recovered and date to Ocucaje Phase 9 and 10 (Figure 3.7). A few fragments of painted Early Nasca pottery were also recovered as was some black ware, a spout and a fragment of negative painted pottery. Other than the wood already mentioned, the only other plant remains from this cemetery were totora reeds (*Typha domingensis*) that were associated with the tomb structure and probably was in the form of a roof or *barbacoa*. Pacay leaves were also recorded in association with the remains of one individual.

Figure 3.7 Diagnostic ceramics recovered from Cemetery 1002. Photograph by author.

Cemetery 1004

Cemetery 1004 is located above the Samaca Basin to the west of the river on the slopes that lead to the Tablazo de Ica (Figure 3.1). It is approximately 70m higher than the valley basin. To the west of the cemetery rises the hillside to the Tablazo and to the east the hillside descends in an irregular slope to the valley.

Cemetery 1004 has been divided into five sectors. These reflect the discrete areas of archaeological material evident from the looting activity. These are all contemporaneous in terms of material assemblage. The area encompassed by all of these sectors is approximately 700m N-S and 250m E-W (Figures 3.8 and 3.9). The size and location of sectors are as follows:

Sector A

This is the south-westernmost area of surface remains. It is roughly an elongated oval in shape orientated on a north-south axis. The N-S dimension is 126m and E-W is 35m. This area is at the eastern base of the slope up to the plateau. The disturbance here was minor. A moderate amount of archaeological material is visible on the surface.

Sector B

This is the largest sector of 1004, with dimensions of 300m N-S and approximately 80m E-W. The shape of this sector follows roughly the shape of this side valley. At the southern end the area of archaeology rises slightly up the slope. This sector was the most heavily looted. A substantial amount of archaeological material is visible on the surface.

Sector C

This sector is located on top of a yardang, a ridge that has been formed by wind erosion, which at its southern end rises above the level of Sectors A, D and E, and at its northern end slopes downwards to the level of the northern end of Sector B. Although the archaeology and looting activity are contiguous with that of Sector B, the division between the two has been made along the line of natural geological change from wind-blown surface sands in Sector B to limestone pieces with some sand in Sector C. The dimensions of this sector are 90m N-S and approximately 20m E-W. Not all the cuts made by the *huaqueros* appear to be associated with adult burials. Some are associated with fragments of large jars, which were perhaps used for storage or infant burials. Infant burials in urns have been recorded for Late Paracas occupation in Jauranga, Palpa valley (Isla 2009). A moderate amount of archaeological material is visible on the surface.

Sector D

Sector D is located to the south-east of the base of the yardang of Sector C. To the south is Sector E and to the east the ground steady declines towards the valley. This Sector is an irregular shape reflecting the random activity by the *huaqueros*. The main area of Sector D is approximately 25x35m (N-S and E-W). Here there is very little *huaquero* activity and likewise, only a small amount of archaeological material on the surface.

Sector E

Sector E is located to the south of Sector D, towards the edge of the level with Sectors A, B, D and E. In plan, this sector is comprised of two adjacent oval areas orientated on a NE-SW axis approximately 54x38m and 32x21m in size. The surface is generally level and covered with archaeological materials due to the wind deflation of the spoil heaps over a long period of time. A substantial amount of archaeological material is visible on the surface.

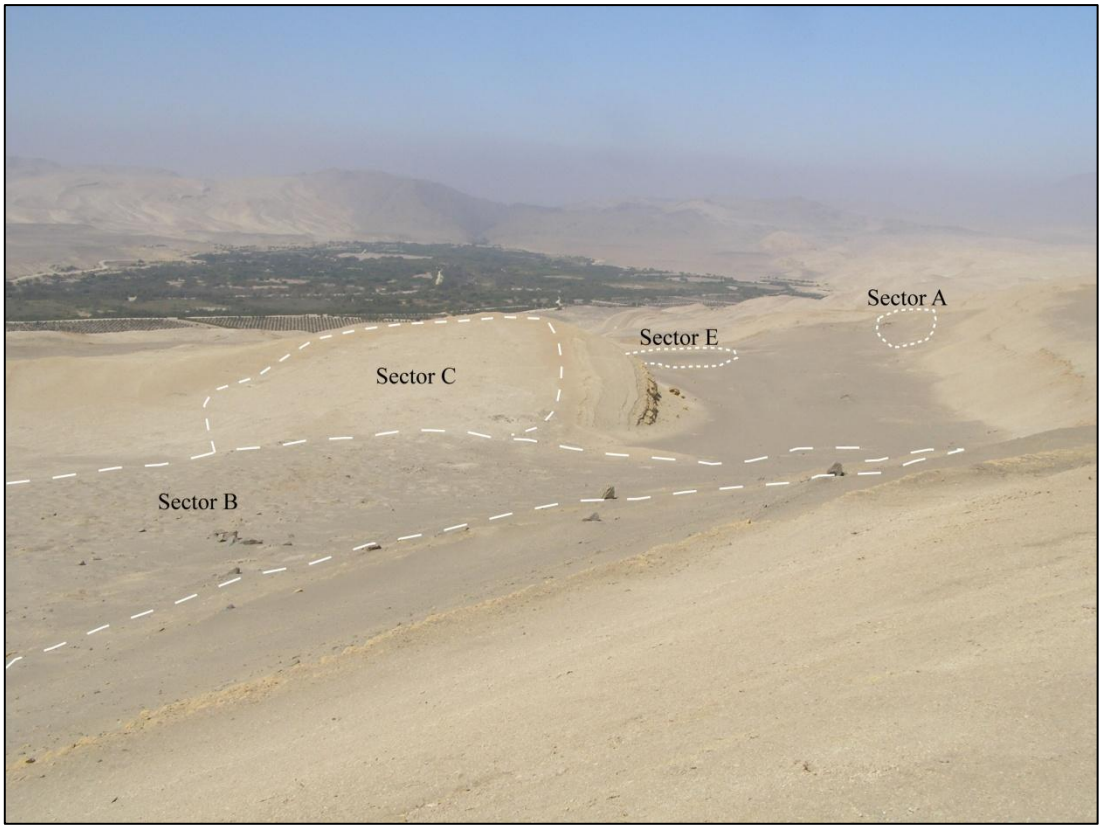

Figure 3.8 Photograph showing four of the sectors of Cemetery 1004, looking south. The Samaca basin is visible in the background. Photograph by author.

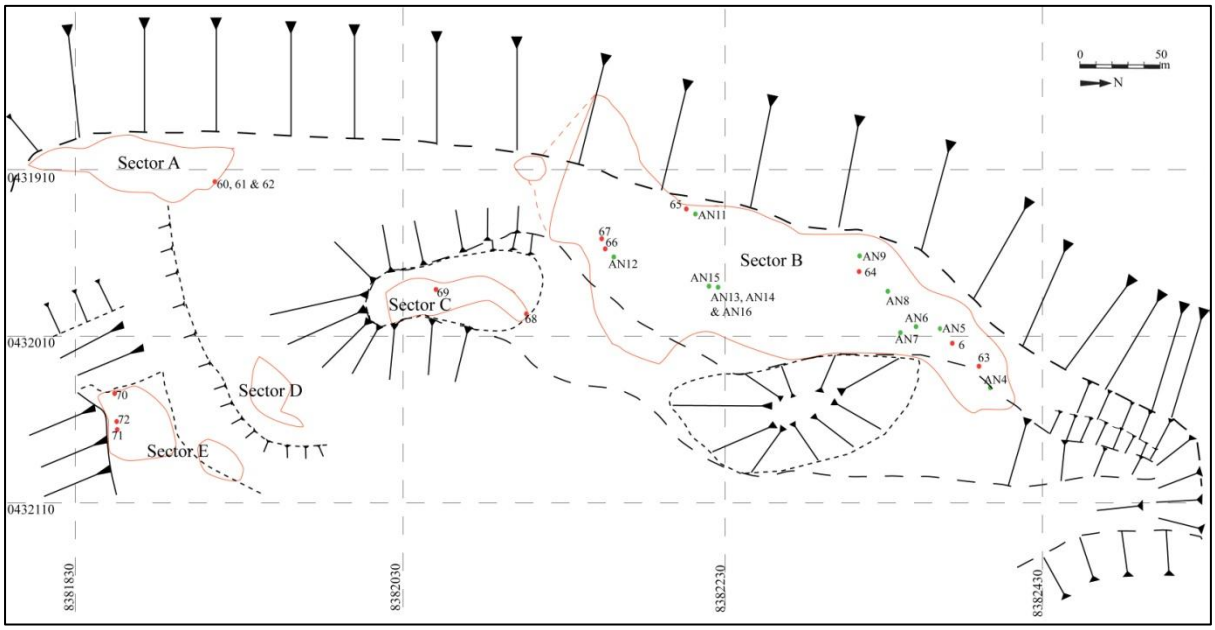

Figure 3.9 Plan of 1004. The topography is drawn in black and the outlines of the sectors in red. The human samples taken are represented by red circles and the faunal samples by green circles. Plan drawn by author.

This site was repeatedly looted although it has not been disturbed for a number of years (A. Galindo *pers. comm.*). The size and depth of the pits indicate that it was looted by hand.

In general the human remains in 1004 were scant. Very few incidences were visible from the surface, but much more animal bone was present and therefore we know that bone survives well in this site even when exposed to the elements. Given this lack of human bone and the presence of artefacts associated with a habitation site, e.g. grindstones, quantity of ceramics, obsidian (Figure 3.10), I believe that 1004 is not a cemetery but in fact a habitation site with burials, although for convenience it will be referred to as a cemetery for the duration of this thesis.

Figure 3.10 Examples of artefacts found in Cemetery 1004. Clockwise from top left: a) obsidian points from Sector B; b) scattered snail shells from the lomas*, Sector B; c) fragment of textile associated with Individual 67; d) fragment of fishing net, Sector A; e) grindstone seen in Sector B. Photographs by author.*

In Sectors A and E only a few incidences of human bone were found and these were mostly in poor condition often with very few skeletal elements present. In Sector D no human

remains were found. Sectors B and C appear to have specific areas of burials, which are possible a continuation of each other.

Not tomb structures were directly observed in this site although there is evidence that may hint at structures. In Sector B there are reeds in the spoil heaps, which may have been used in tomb structures, e.g. roofing, or possibly in habitation structures, e.g. *quincha* (woven reed structure).

Faunal remains were mostly concentrated in Sector B. Camelid bones, including immature animals, were most abundant although bird and rodent bones were also sampled. At the northern extreme of Sector B a concentration of camelid bones was observed. Marine shells and *lomas* snail shells were also present in all sectors (very few in Sector D). The *lomas* snail shells were often found in large concentrations in spoil heaps of the looters pits.

Archaeological material was ubiquitous across all sectors with the exception of Sector D. In general the assemblages in each sector were of the same nature, although concentrations of artefacts varied between the sectors.

Figure 3.11 Examples of the ceramics recovered from 1004. Photographs by author.

The ceramics recovered include black incised ceramics, coloured incised ceramics, *queñas* (panpipes), painted vessels and a fragment of a figurine and date to the ceramic phases Ocucaje 9 and 10 and Nasca 1 (Figure 3.11). A small number of Nasca phase 2/3 fragments were recovered from the northern extreme of Sector B.

Cotton was observed in Sectors A as fishing nets (Figure 3.10d) and in B as raw cotton. A fragment of a border of a textile (Figure 3.10c) was recovered in association with one of the individuals sampled (number 67), with a design dating to the Late Ocucaje. Plain woven cotton cloth was associated with some other individuals sampled although this was extremely fragile and poorly preserved.

Few plant remains were observed including maize, peanut, pacay, manioc and squash. The most notable artefacts observed were obsidian points. These were numerous and mainly found in Sectors A, B and E. The majority of them were broken points, unlikely to have been used due to their mis-manufacture. Two larger pieces of obsidian were also found in Sector B. These have both been worked and appear to be larger blades that have been broken.

Wooden artefacts were observed - a post in Sector A and a shovel in Sector E. Two grindstones were observed in Sector B.

3.2.2 The Early Intermediate Period Cemetery

Only one cemetery (734) is known to date to the latter part of this period in the Samaca and Ullujaya basins and therefore the number of samples taken was limited.

Cemetery 734 is located at the edge of the Ullujaya basin to the west of the river (Figure 3.1). It is situated at the base of the slope leading up to the Tablazo de Ica. Its north-western edge meets the base of a steep incline and the south-eastern edge is delimited by the top of a ridge. There is also a small section situated just below this ridge which is bounded to the east by the modern irrigation canal (Figure 3.12).

This cemetery has been divided into two sectors. Sector A is the main part of the cemetery (the level ground between the ridge and base of slope to the Tablazo) and is orientated on a NE-SW axis. Its approximate size is 105x41m. Sector B is located to the north-east of Sector A and on a slightly lower level. It is much smaller in size - approximately 35x15m. Although the two sectors are slightly different in the composition of archaeological materials present they are thought to be contemporaneous. Both sectors have been repeated disturbed by looters as is evident by the reburial or partial reburial of sun-bleached bones.

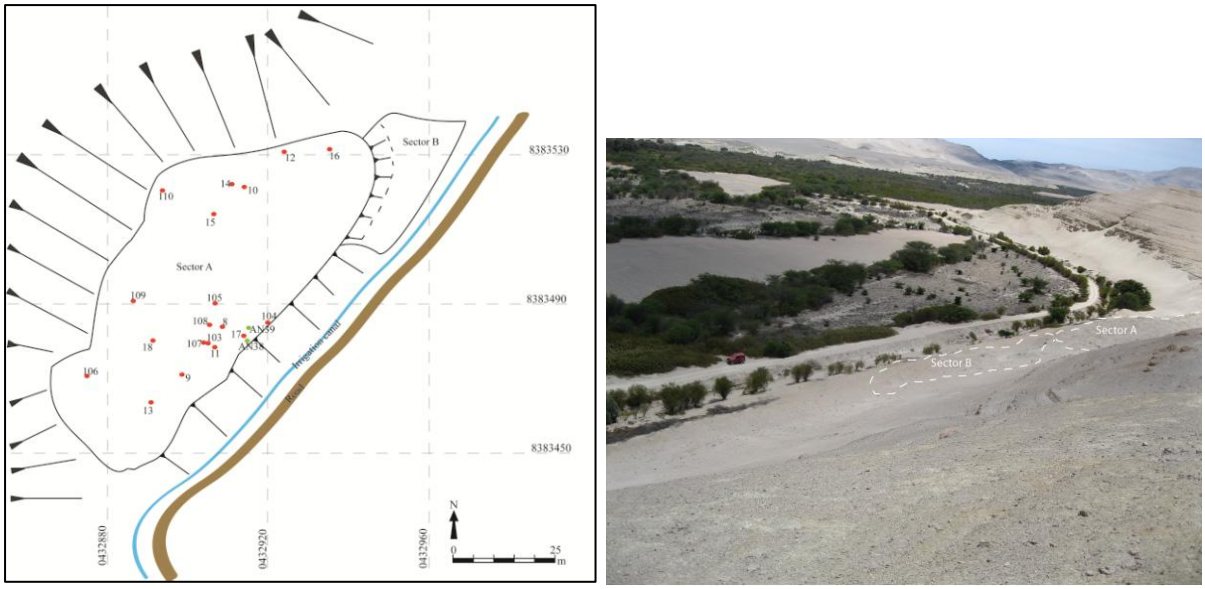

Figure 3.12 Left, plan of Cemetery 734. Right, photograph of the cemetery from the southeast. Photograph and plan by author.

There is some evidence for tomb structures. Reeds and a piece of huarango trunk are present on the surface in Sector A although they are no longer *in situ*. There is a one metre piece of *quincha* that appears to be *in situ*, although it is not possible to identify the shapes of any graves. Structures made of reeds have been reported for other Early Intermediate Period tombs from the Ica Valley (Pezzia Assereto 1968: 178). There are many fragments of *ollas* which may have been funerary vessels, but this is difficult to establish. In Sector B there are looted pits with large wooden posts and smaller posts still *in situ*.

There are few incidences in this cemetery of well preserved soft tissue remains and articulated body parts - both for humans and animals. In Sector B there are fewer human remains on the surface than in Sector A. There are some cases of cranial deformation both circumferential and anterio-posterior.

Both plain and decorated ceramic fragments are present on the surface. The diagnostic pieces have been identified as belonging to Late Nasca Phases (Figure 3.13).

There are only a few incidences of plant remains on the surface including a *pallar* pod (*P. lunatus*). There are notable concentrations of shellfish shells (mussels) in Sector B.

Figure 3.13 Ceramics collected from Cemetery 734. Photographs by author.

3.2.3 The Middle Horizon Cemeteries

Two Middle Horizon cemeteries, both located in Ullujaya, were studied in this research. Both had been surveyed in 2007 (Beresford-Jones *et al.* 2011a). However, since that survey one cemetery (755) has been further destroyed by modern engineering works, contrary to Peruvian law.

Cemetery 398

Cemetery 398 is located to the west of the river, mid-way up the slopes at the side of the valley, where the hillside levels out. As well as the underlying laminated sedimentary rock, the surface of the cemetery is covered with wind deposited sand that appears to have been mostly deposited after looting. The extent of looted tombs runs along the edge of hill to the west but not the edge of the ridge (to the east) for the complete length (Figure 3.14). This presumably is a reflection on the original shape of the cemetery. The N-S dimension of the cemetery is 143m, with a width of 15m E-W at the southern end and 22m at the northern end. The cemetery has not been divided into sectors and the disturbance caused by the looters is heavy (Figure 3.15).

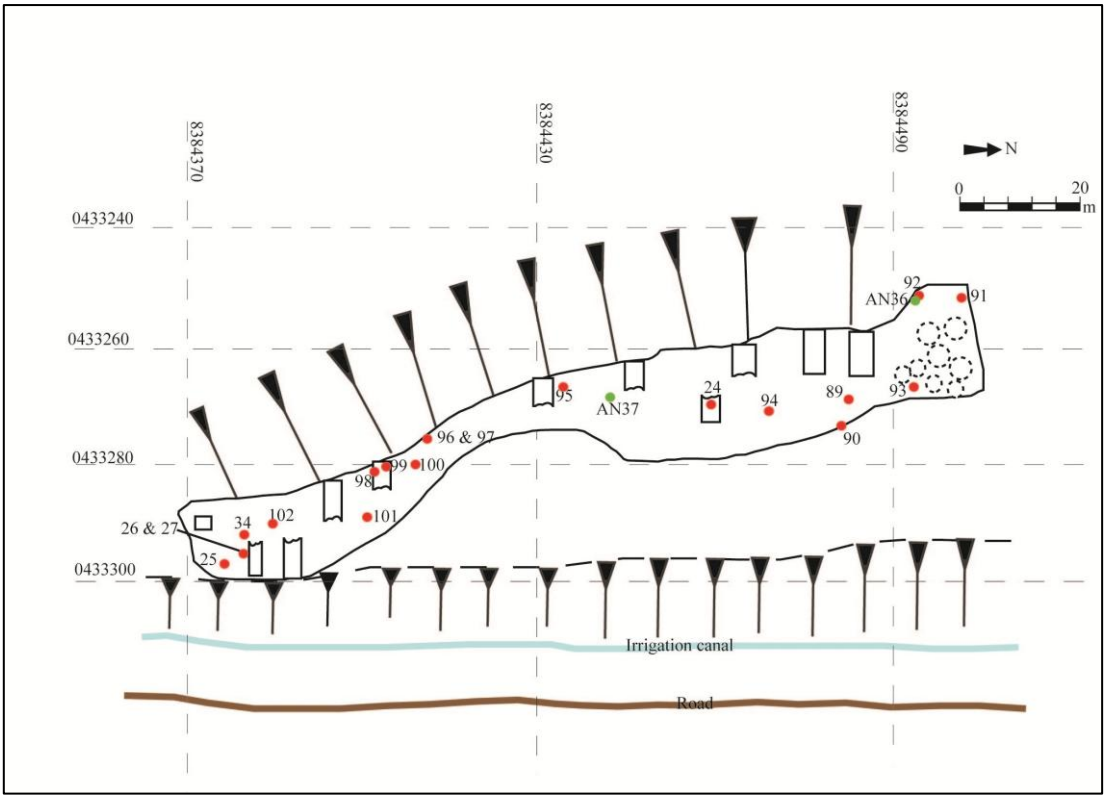

Figure 3.14 Plan of Cemetery 398. Tomb structures are represented by the rectangles, looted pits by the dashed circles. The human samples taken are represented by red circles, and the faunal samples by green circles. Plan drawn by author.

Figure 3.15 A view of cemetery 398 (looking north), illustrating the amount of damage caused by the huaqueros. *Photograph taken by A. G. Pullen.*

Tomb architecture, in the form of adobe bricks with mud mortar, is present although in places it is very disturbed (Figure 3.16). Tombs are rectangular with the long axis aligned east-west, but this can only be confidently observed for a few tombs as most are heavily truncated. Large huarango beams are often found by or in tomb structures (one is *in situ*) and would have supported the roof of the tomb. There is also an example at the northern extreme of the cemetery of a tomb that has been constructed using the natural rock for the western wall and smaller rocks have been used in the other walls. The widths of two observed tombs, spaced 6m apart, at the northern end of the cemetery were 1.75m and the lengths have been observed for these tombs as 4.50m and approximately 7m. The size of these tombs suggests that these were used for multiple individuals as has been observed elsewhere (Isla 2009; Pezzia Assereto 1968). Many tombs have been completely destroyed by the looters but the depressions provide an idea of where the tombs would have been. These tombs are of a similar style although larger than others of the same period excavated in the Nasca-Palpa area (Isla 2009).

Figure 3.16 Examples of the tomb architecture observed in Cemetery 398. Photographs by author.

Human remains are scattered across the entire cemetery. There are some incidences of articulated remains, particularly at the northern end of the cemetery where the disturbance is greater. Exposed bone is very sun bleached. Skin and hair can be found in many cases if only in fragments on bones. There is little evidence for fauna based on surface materials, although some samples were collected.

Fragments of Middle Horizon style painted ceramics were recovered (Figure 3.17). The amount of raw cotton as well as the designs on the textiles also indicate that this cemetery dates to the Middle Horizon. Few other artefacts remain.

Figure 3.17 Middle Horizon ceramics collected in Cemetery 398. Photograph by author.

Cemetery 755

Cemetery 755 is located within the Ullujaya basin (Figure 3.18). It is to the west of the river and is the northernmost cemetery in this study. The ground here is duracrete (compact sandy-silt) and the surface level is irregular although generally flat. Judging by modern truncation of the archaeological deposits, the duracrete extends to quite a depth below the surface and suggests that this land was once wet prior to the construction of the cemetery. The approximately size of this site is 200x150m (Figure 3.19). However, it is unclear if this encompasses all of the tombs or if there are some undisturbed tombs which are not visible from the surface. This site has not been divided into sectors.

Figure 3.18 Position of Cemetery 755 (marked in white) in the Ullujaya basin. Looking east-northeast. Photograph by A. G. Pullen.

This cemetery is the most badly damaged of all the cemeteries used in this research. The cemetery was badly looted, with remains scattered across the surface. This has occurred several times - evident by buried sun-bleached bones. A large trench was machine dug with a machine through the cemetery as part of a water management scheme. The trench is L-shaped, with the long side orientated NW-SE (see Figure 3.20). It is approximately 8m in width and 3m deep. The long side is approximately 168m and the shorter 59m. It has been dug straight through several tombs as is evidenced by the remnant tomb walls in the side of the trench. This has caused further damage to the human remains.

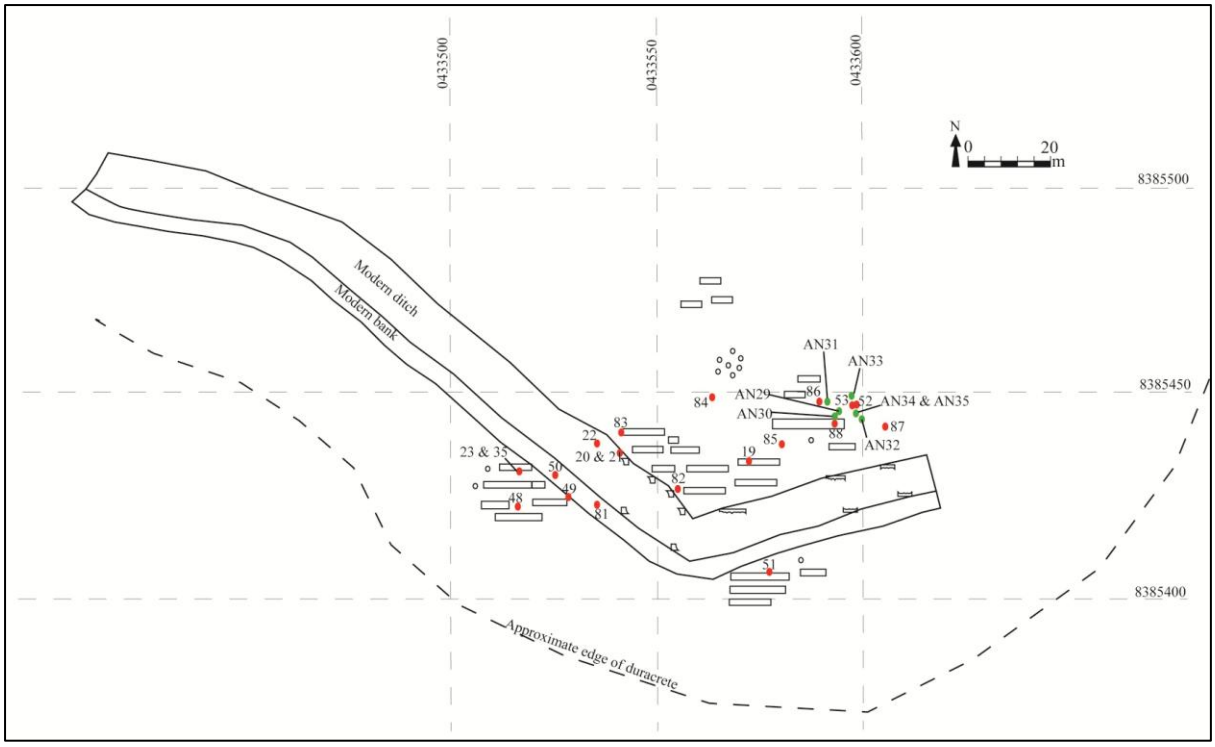

Figure 3.19 Plan of Cemetery 755. The red circles indicate the location of the human samples and the green circles represent the faunal samples taken. Plan drawn by author.

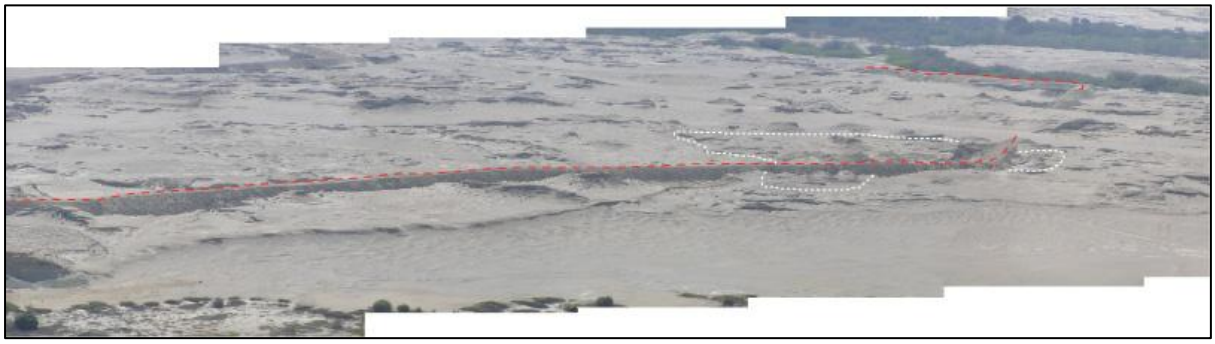

Figure 3.20 The destruction of Cemetery 755. The modern canal is marked in red and the cemetery in white. Photographs by A. G. Pullen.

The tombs are rectangular in shape and orientated east-west, some having a lining of adobe bricks (Figure 3.22). They are large, approximately 10m long by 1m wide, and would have acted as communal tombs. There are also several incidences of small round cuts, probably single graves for children, which are 50cm in diameter. The rectangular tombs are very similar to those described by Pezzia Assereto (1968), which were observed in Ullujaya.

These tombs were communal, roofed with huarango beams and contained multiple mummy bundles measuring 86cm in diameter and 47cm tall (see Figure 3.21). These were wrapped in both plain and decorated cotton textiles.

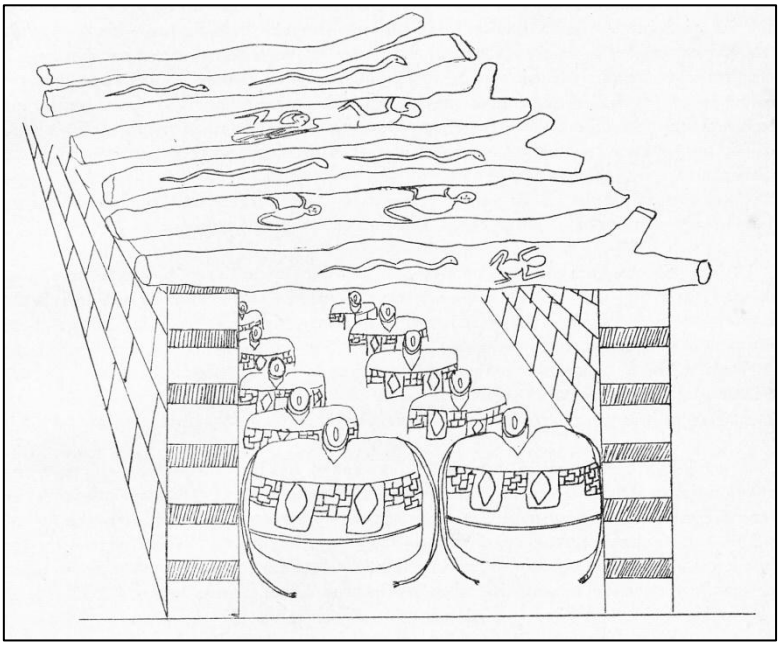

Figure 3.21 Drawing of a communal Middle Horizon tomb from Ullujaya from Pezzia Assereto (1968: fig 38).

Figure 3.22 Examples of the tomb architecture of Cemetery 755. The photograph on the right is looking southeast. Photographs by author.

The human remains in this cemetery have been badly damaged due to the activity of the looters as well as by the modern irrigation works. However, the organic components of the corpses are still well preserved (Figure 3.23) and have not been degraded by the sun and wind to the extent seen in the other cemeteries. The remains can be found scattered across the entire site. There are many examples of articulated remains, well preserved skin and long, well preserved scalp hair. Faunal remains were scant and of those observed all were camelids.

Figure 3.23 Photographs illustrating the level of preservation of organic remains as well as the destruction of the cemetery. Photographs by author.

Many decorated fragments of pottery were recovered from the surface of this cemetery (Figure 3.24). The majority of these were Middle Horizon. Three fragments identified as Late Intermediate Period ceramics were found also. This is an insignificant quantity compared to the number of Middle Horizon ceramics and therefore it does not compromise the dating of this cemetery. Additionally a considerable amount of cotton was present (Figure 3.23), which is characteristic of Middle Horizon burials.

Figure 3.24 Middle Horizon style ceramics recovered from Cemetery 755. Photograph by author.

There are some plant remains at the site although these are not numerous, with the exception of cotton. Plants observed are maize, beans, guayaba and pacay. Compared to Cemetery 398, there were more artefacts present on the surface of this cemetery including, spondylus fragments and copper fragments.

3.2.4 The Late Intermediate Period Cemetery

Only one Ica-Chincha cemetery was used in this research as it alone provided a large enough sample size.

Cemetery 1003 is located in the Samaca basin edge to the west of the river (Figure 3.1). It is at the base of the slopes that lead to the southern end of Cemetery 1004. To the east it is cut by the modern irrigation ditch and road. Cemetery 1003 was divided into two sectors (Figure 3.25 and 3.26). Sector A is the northern part of the cemetery. It is an area of mixed remains, with ceramics dated to Early Intermediate Period, Middle Horizon and Late Intermediate Period. In plan it is an irregular shape and comprises of approximately one fifth of the cemetery. This sector was not sampled due to its mixed nature. Sector B comprises the rest of the cemetery. It is approximately 176m by 161m.

Figure 3.25 Panoramic view of Cemetery 1003 looking east. Photograph by A. G. Pullen.

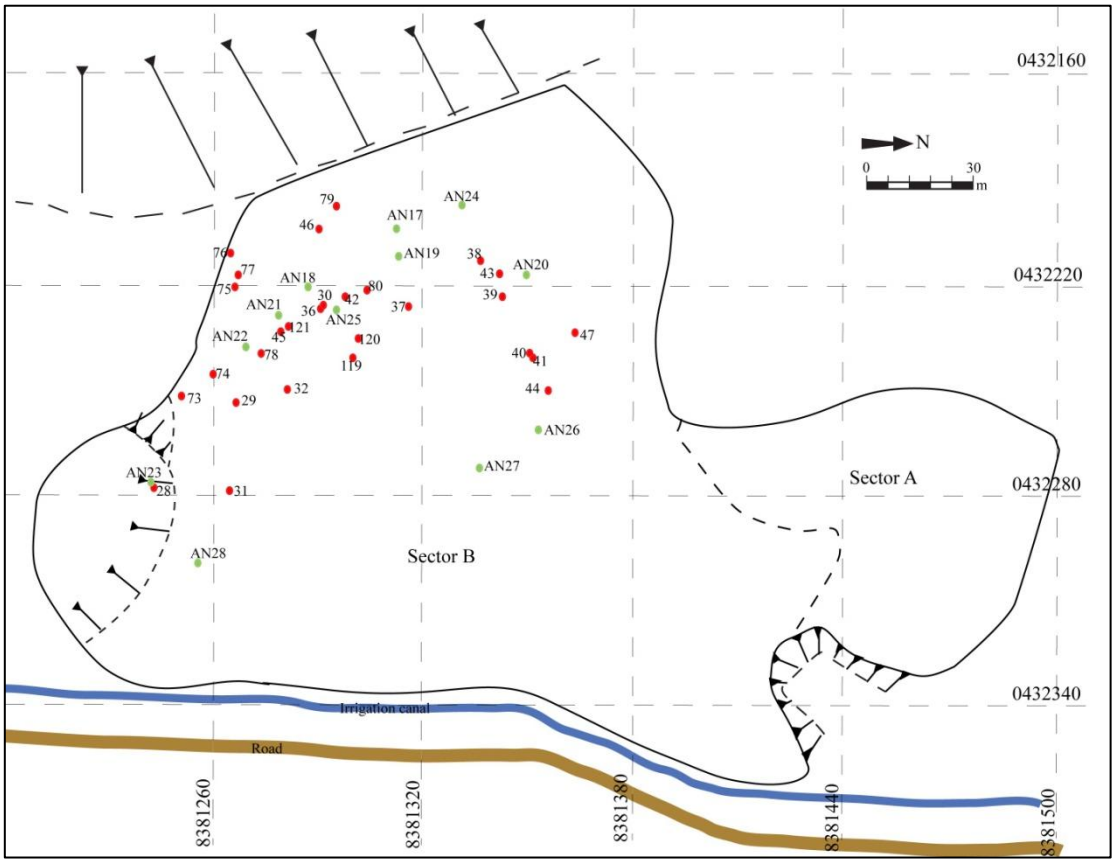

Figure 3.26 Plan of Cemetery 1003. The red circles indicate the location of the human samples and the green circles represent the faunal samples taken. Plan drawn by author.

The looting activity was less intense in Sector A and it is probable that this had been dug by hand, whereas Sector B is intensely disturbed, clearly representing a large scale mechanical excavation. This area has been dug over several times and sun-bleached material is found

reburied under sand. The damage to the artefacts as well as the human and faunal remains is severe.

In Sector B there is one clear adobe tomb structure similar to other Middle Horizon burials in this part of the valley. Other than this there are no other tomb structures. However, there are huarango beams/posts and adobe bricks scattered on the surface of the cemetery.

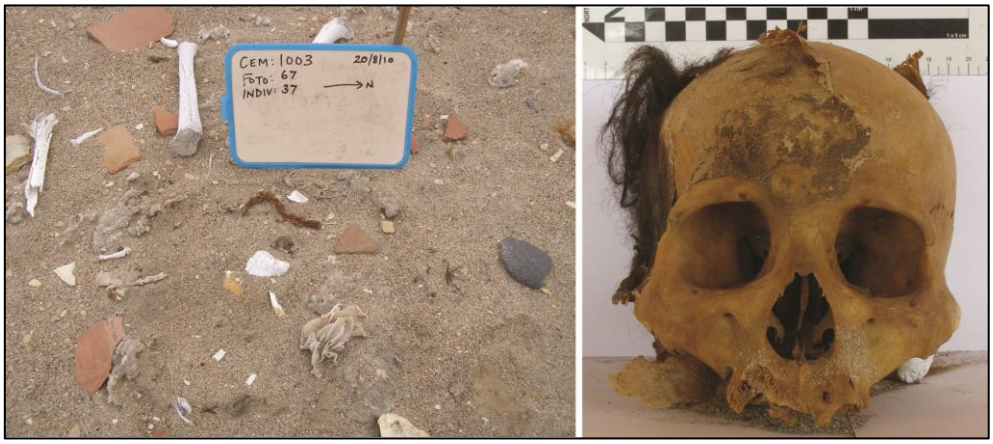

Figure 3.27 The surface remains of Cemetery 1003, with the left mastoid process of Individual 37 just visible skull (left); and the skull of Individual 37 (right). Photographs by author.

The surface is littered with human and animal bones with examples of all skeletal elements present (Figure 3.27). Some of the human material is articulated with soft tissue preservation. There are also many incidences of loose hair attached to a piece of scalp but with no obvious association to any skull. The majority of animal remains observed were camelid bones. Like the human remains they had suffered severe sun and wind damage. Some faunal bones still had wool attached although this was often badly damaged by the sun and wind. There was a notable absence of *lomas* snail and marine shells, which have been observed in all of the other cemeteries.

The ceramics recovered from Sector B date to the Late Intermediate Period (Figure 3.28). Numerous textiles, both fine and coarse, were also observed on the surface.

Figure 3.28 Late Intermediate Period ceramics from Sector B of cemetery 1003. Photographs by author.

Plant remains were found scattered across the cemetery. The most frequent type were utilitarian plants, i.e. cotton (both processed and raw) as well as plant fibre cords. There were also edible plant remains such as maize and gourd. Other artefacts observed on the surface of the cemetery include: spondylus, occasional small metal fragments and occasional beads (including turquoise).

3.3 Summary

Seven cemeteries have been sampled for this research - three for the Early Horizon, one for the Early Intermediate Period, two for the Middle Horizon and one for the Late Intermediate Period. The cemeteries were selected based on the availability of remains and the homogeneity of the ceramics present in terms of the phases that they dated to. All of the cemeteries bar one (Cemetery 755) are located on the western edge of the valley on the hills flanking the basins. The degree to which the cemeteries have been looted varies as does the

preservation of the human remains, which will be discussed further in Chapter 5. There are notable differences in the burial practices between the four periods that can be observed despite the looted nature of the cemeteries. Full details of all the samples taken from each cemetery are given in Chapter 5.

Chapter 4 Scientific Background

Isotopic analysis of the humans remains collected in the seven cemeteries forms the core of this research. This chapter details the principles of stable carbon and nitrogen isotopic analysis and their use in palaeodietary reconstruction. The physical properties of the four tissue types used in this research - bone, skin, tooth and hair - and what the isotopic composition of these reflect are detailed next. Finally, the limitations of the technique and the possible issues with preservation of the samples and organic contents are discussed.

4.1 The Principles of Isotopic Analysis

In the discipline of archaeology, isotopic analysis is an extremely useful tool for investigations into mobility, diet, dating and climate reconstruction (see Katzenberg 2008 and Lee-Thorp 2008 for reviews). The palaeodietary reconstruction reported here uses the light stable carbon and nitrogen isotopes. This chapter explains the principle behind this analysis and the structure of the four tissues - bone, skin, tooth, hair - that were used.

4.1.1 What are Isotopes?

An isotope is a variety of an element that has a different number of neutrons in the nucleus (Hoefs 2004). Lighter stable isotopes make up the largest proportion of each element (Ambrose 1993) and the relative abundances of the different isotopes of a given element are essentially constant in nature (Schwarcz and Schoeninger 1991). For example, the most abundant stable isotope of nitrogen is ^{14}N, which makes up 99.634% of the nitrogen in the atmosphere. The heavier ^{15}N has an extra neutron and makes up only 0.366% of atmospheric nitrogen (Schoeller 1999). The difference in the masses of the isotopes will affect their rate of movement, chemical reaction and transition of state (Ambrose 1993; Hoefs 2004), causing discrimination, known as fractionation, usually against the heavier isotopes of an element (Ambrose 1993; DeNiro 1987; Schoeller 1999). For carbon and nitrogen isotopes in plant and animal tissues, fractionation occurs with each step up the food chain, creating trophic level steps (Chisholm 1989; Schoeller 1999). The difference between the isotopic composition of the consumer and the food source is usually systematic, causing an enrichment or depletion, which makes the effects of a known dietary change predictable (Ambrose 1993). For example, as trophic level increases there will be an enrichment of ^{15}N.

Use of stable isotopes for dietary reconstruction is based on the assumption that the isotopic composition of the animal's tissues is a direct and constant function of their diet (Ambrose 1993). This has lead to isotopes being thought of as 'you are what you eat' although as discussed in Section 4.3 this is not strictly true (Ambrose 1993; Schoeller 1999). The isotopic composition of different dietary resources can be quantified, with foods being grouped into a number of isotopically distinct groups allowing dietary reconstructions (Ambrose 1993; DeNiro 1987; Sillen *et al.* 1989). Resources can contribute to the consumer's isotopic signal both directly, via straight consumption, and indirectly, via consumption by a lower trophic member which is later consumed itself. Before dietary reconstruction is attempted using human isotopic data it is imperative to understand the isotopic context of their diet - i.e. the isotopic values of all the resources that are part of the local food chain (Cadwallader *et al.* 2012; Llano 2009).

Stable isotope measurements are reported using the delta notation (Hoefs 2004; Sealy 2001), where, using carbon as an example:

$$\delta^{13}C = \left(\frac{\left({}^{13}C/{}^{12}C \right)_{sample}}{\left({}^{13}C/{}^{12}C \right)_{standard}} - 1 \right) \times 1000‰$$

Thus a more negative $\delta^{13}C$ values means a lighter mass (more ^{12}C) and vice versa (O'Leary 1988). These values are measured against international standards to eliminate variation across mass spectrometers and enable direct comparison of results between different laboratories. The standard for $\delta^{15}N$ is AIR - atmospheric inhalable reservoir - and for $\delta^{13}C$ Peedee Belemnite (PDB) (Hoefs 2004; Sealy 2001).

4.1.2 Carbon Isotopes

Atmospheric carbon dioxide is made of up of approximately 1.1% ^{13}C and 98.9% ^{12}C, both stable isotopes (O'Leary 1988). During photosynthesis plants discriminate against ^{13}C in minor amounts caused by its heavier mass (Ambrose 1993; O'Leary 1988). The method of photosynthesis utilised is linked to the isotopic fractionation with more water-efficient plants having more positive $\delta^{13}C$ values (O'Leary 1988). Thus plants belonging to the different pathways can be broadly characterised into being hot, dry climate species (C_4) and cold, wet climate species (C_3) (Tieszen and Boutton 1989).

Plants that use the Calvin-Benson pathway fix CO_2 by the action of the enzyme ribulose biphosphate carboxylase, are referred to as C_3. There are only two important steps in CO_2 uptake in terms of carbon fractionation. Firstly, external CO_2 diffuses through the boundary layer into the internal gas space. This movement of CO_2 is to some extent reversible. Secondly, the internal CO_2 then dissolves and diffuses into the chloroplast where carboxylation of ribulose biphosphate occurs. This carboxylation step produces the biggest fractionation effect and is not reversible. Subsequent steps are not important in determining fractionation (O'Leary 1988). C_3 plants typically have $\delta^{13}C$ values in the region of -33‰ to -23‰ relative to atmospheric values of -8‰ and characteristically grow in temperate areas with winter rainfall, high latitude or high altitude (O'Leary 1988; Sharp 2007; Tieszen 1991; Tieszen and Boutton 1989). In the context of South America, the vast majority of staple foods are C_3 plants, for example potatoes, quinoa, squashes and legumes (DeNiro and Hastorf 1985). The average modern plant value for native Peruvian C_3 south coast plants is -25.7‰ (Cadwallader *et al.* 2012). However, due to the burning of fossil fuels being in modern industrial times, the $\delta^{13}C$ value of atmospheric CO_2 has decreased. Modern and archaeological samples are thus not directly comparable in terms of $\delta^{13}C$ values unless a correction factor is added to modern samples (Hoefs 2004:145; Long *et al.* 2005; Marino and McElroy 1991; van Klinken *et al.* 2000). This correction factor depends on the date that the specimen came from, with more recent samples having higher correction factors than those 50 or 100 years older (Long *et al.* 2005). This is important to consider when using modern plant values as a reference for the isotopic signature of the food chain. Therefore the average $\delta^{13}C$ value of modern native south coast plants from Peru, -25.7‰ (Cadwallader *et al.* 2012) is in the region of 1.5‰ lower than it would have been during Pre-Columbian times (Long *et al.* 2005).

Plants using the Hatch-Slack pathway use a different method of photosynthesis and are known as C_4 plants. Briefly, the fixing of CO_2 occurs through the following steps. External CO_2 enters the stomata and is taken up by phosphoenolpyruvate carboxylase in the mesophyll cells. This step is irreversible and causes the fractionation seen in the $\delta^{13}C$ values of C_4 plants. The product of this carboxylation is converted in aspartate or malate and transported into bundle sheath cells where it is converted into CO_2 and other compounds. This CO_2 then under goes carboxylation by the ribulose bisphosphate carboxylase enzyme (O'Leary 1988). The $\delta^{13}C$ value of these plants are typically in the range of -16‰ to -9‰, although the values can be as low as -21‰ (Hatch and Slack 1966; O'Leary 1988; Sharp 2007; Tieszen 1991). C_4

plants tend to grow in hot, sunny, dry habitats at lower altitudes (Tieszen and Boutton 1989). There were only two domesticated C_4 plants in pre-Columbian South America - maize and kiwicha (*Amaranthus caudatus*). Given that the south coast is a hot, dry environment, C_4 wild plants are more abundant in this region than in the highlands. The average modern C_4 plant value for native Peruvian south coast plants is -13.8‰ (Cadwallader *et al.* 2012), which again is approximately 1.5‰ lower than in the pre-Columbian era (Long *et al.* 2005).

CAM, or Crassulacean Acid Metabolism, plants can have $\delta^{13}C$ values that span the range of C_3 and C_4 plants. CAM plants, of which cacti and succulents are the main types, are able to use two forms of photosynthesis. During the day they engage in C_3 photosynthesis as described above. At night CO_2 is absorbed through the stomata and the plant uses a process similar to that of C_4 plants involving phosphoenolpyruvate carboxylase and malate dehydrogenase. (Ambrose 1993; DeNiro 1987; O'Leary 1988; Sealy 2001). The extent to which the plant uses each pathway is influenced by their environmental setting, which is reflected in their $\delta^{13}C$ value (O'Leary 1988). For example, CAM plants in hot, dry conditions will have $\delta^{13}C$ values that reflect use of the pathway similar to that of C_4 plants (Cadwallader *et al.* 2012; Eickmeier and Bender 1976), and so may become isotopically indistinguishable from C_4 plants.

There is a slight fractionation of carbon isotopes as the food chain is ascended. This is approximately of the order of +1‰ (DeNiro and Epstein 1978b). Humans with a wholly C_3 diet would therefore be expected to have $\delta^{13}C$ values in the region of -20‰, whereas C_4 consumers would have values in the region of -10‰ in their bone collagen values.

Salinity, aridity, nutrient availability, temperature, irradiance and atmospheric pressure will also have some effect on the $\delta^{13}C$ value of plants due to a change in either the stomatal conductance or enzyme activity (O'Leary 1988; Tieszen 1991). Variability to the order of several parts per mil in the $\delta^{13}C$ values between plant species from the same locations caused by localised differences in the growing conditions, i.e. irradiance, temperature, and water availability, as well as altitudinal differences upon the same slope, have been observed (Körner *et al.* 1988; Körner *et al.* 1991; Sparks and Ehleringer 1997; Tieszen 1991; Tieszen and Boutton 1989; Tieszen and Fagre 1993a; van de Water *et al.* 2002; van Klinken *et al.* 2000; Vitousek *et al.* 1990; Vitousek *et al.* 1988; Wang *et al.* 2008). Different parts of the same plant, such as leaves and seeds, have also been shown to have varied $\delta^{13}C$ values due to

the small variation in isotopic composition of their individual components, e.g. protein, lipids, cellulose, of the plant (Tieszen 1991; Tieszen and Boutton 1989).

The canopy effect is the depletion in $\delta^{13}C$ values associated with densely forested environments, such as the Amazon rainforest (van der Merwe and Medina 1991). C_3 plants are the dominant type of plant as the forest is shaded by the high canopy. Plants in this type of environment have $\delta^{13}C$ values of approximately -30‰ to -37‰, with plants nearer the ground having lower values than plants nearer the canopy (van der Merwe and Medina 1991). This is due to the recycling of plant-fractionated respired CO_2 underneath the canopy causing a depletion in the local atmospheric CO_2 $\delta^{13}C$ values (van der Merwe and Medina 1991; van Klinken *et al.* 2000). This is unlikely to have any bearing on the samples used in this research.

4.1.3 Nitrogen Isotopes

The main source of nitrogen into a food web is from atmospheric N_2. In terrestrial environments this is first fixed by soil dwelling microorganisms into the soil matrix before being immobilised by the microorganisms becoming available to plants (Sharp 2007:207). As the nitrogen transcends the food chain from soils to plants and then animals, there is a systematic increase in the $\delta^{15}N$ values due to fractionation occurring. Nitrogen-fixing plants, such as legumes, are not dependant on the soil for nitrogen and therefore the plants have lower $\delta^{15}N$ values close to atmospheric $\delta^{15}N$ values (for example see DeNiro and Hastorf 1985; Yoneyama *et al.* 1990).

Nitrogen isotopes are used in differentiating herbivore, omnivore and carnivore trophic levels, as well as estimating the degree of carnivory (Ambrose 1993; Ambrose 2000; O'Connell and Hedges 1999a), with differences being noted in humans who ate animal produces rarely, occasionally, and frequently (O'Connell and Hedges 1999a). In terms of trophic level there is no difference between primary and secondary protein sources, e.g. meat and milk, and thus there is no discernible difference in $\delta^{15}N$ values between the two (Macko *et al.* 1999a; O'Connell and Hedges 1999a). Infants that are breast fed will show an increase of $\delta^{15}N$ values in comparison to the adults, as they are effectively consuming their mother, with a decrease in $\delta^{15}N$ values when the weaning process commences (Katzenberg *et al.* 1996). Thus in order to understand a person's trophic position it is imperative to have a faunal isotopic baseline. Physiological stress can also affect the $\delta^{15}N$ values of human and animal tissues. During periods of stress, such as malnutrition and chronic sickness, $\delta^{15}N$ values have

been observed to increase (Fuller *et al.* 2004; Fuller *et al.* 2005; Hobson *et al.* 1993; Mekota *et al.* 2006). This is caused by catabolism of the body's own protein, thereby causing fractionation as seen for 'normal' trophic increases.

Nitrogen isotopes in plants can be raised by the introduction of natural or chemical fertiliser to the soil. Fertilisers such as guano and animal dung have high $\delta^{15}N$ values and therefore raise the soil $\delta^{15}N$ value. This higher $\delta^{15}N$ value is then transported up the food chain via plants and animals (van Klinken *et al.* 2000). Environmentally stressful conditions, such as heat stress, aridity, and inadequate nutrition, can affected nitrogen isotope values in plants and animals. In hot, arid conditions less N_2 is incorporated in to the soil matrix as these conditions inhibit nitrogen fixation, causing an increase in soil $\delta^{15}N$ values (Ambrose 1991). In turn the plants living in these type of environments have elevated $\delta^{15}N$ values compared to temperate, well watered conditions. Drought adapted animals also have increased $\delta^{15}N$ values in comparisons to their counterparts (Ambrose 1991; Sealy *et al.* 1987). They adapt to their environment by being able to recycle urea (NH_3), thus conserving water causing further fractionation in nitrogen (Sealy *et al.* 1987). However, multiple observational studies have not reached a common consensus on the isotopic effect that can be expected in water-stressed animals (Ambrose 2000; Sealy *et al.* 1987; Sponheimer *et al.* 2003a).

4.1.4 Marine and Freshwater Food Webs

Marine and freshwater resources fall into distinct isotopic groupings with respect to both $\delta^{15}N$ and $\delta^{13}C$. Carbon sources in aquatic systems can be from atmospheric or dissolved CO_2, carbonates, bicarbonates or decomposing plant material. The $\delta^{13}C$ values of these source carbons can differ widely and their use will be reflected in the $\delta^{13}C$ value of the plant (Osmond *et al.* 1981). When multiple sources are available, other factors, such as pH of the water, relative proportion of those source and flow rate of rivers, will have an effect on which is used (Allen and Spence 1981; Osmond *et al.* 1981). Most aquatic plants use the C_3 photosynthesis pathway, although some C_4 aquatic plants are known and a wide range of isotopic values have been observed in aquatic plants (Smith and Epstein 1971; Ueno *et al.* 1988). Animals from marine and freshwater systems can be differentiated by the $\delta^{13}C$ value of their tissues, with marine systems having more positive values than freshwater, although there is some overlap between the two (Schoeninger and DeNiro 1984). Therefore the specific isotopic food webs should be known when reconstructing palaeodiet (Ambrose 1993; Hoefs 2004; O'Connell 2005; Schoeninger and DeNiro 1984; Schwarcz and Schoeninger 1991).

Nitrogen isotope values allow aquatic resources to be distinguished from terrestrial environments (DeNiro and Epstein 1978b; Schoeninger and DeNiro 1984). Both freshwater and marine systems have elevated $\delta^{15}N$ values compared to terrestrial resources due to the greater length of the food chain. Within these systems it is also possible to elucidate the trophic position of the animal based on the $\delta^{15}N$ value (Schoeninger and DeNiro 1984). The difference of $\delta^{15}N$ between marine and terrestrial animals is almost 10‰, largely due to the absence of herbivores and abundance of carnivores in aquatic systems (DeNiro 1987).

4.2 Human Tissues as Chronological Indicators

Four different tissue types from human remains are used in this research - bone, skin, tooth (dentine) and hair. Due to the differences in formation and structure of the tissues it is possible to retrieve information at different life stages and over different time scales from the same individual. In the case of bone, skin, and teeth, collagen is the extracted component that will be analysed. Hair is effectively all keratin and so the whole hair is analysed isotopically here.

4.2.1 Structure and Composition of Bone

By weight, bone is composed of 70% inorganic material, 20% organic material and 10% water (Ambrose 1993; Ezzo 1994; Schwarcz and Schoeninger 1991). The organic material is namely Type I collagen, which is comprised of three α chains - two α1 and one α2 chains (Wenstrup *et al.* 1991). The chains are arranged in a triple helix structure bound together with hydrogen bonds (Wenstrup *et al.* 1991). The collagen molecule is arranged with others to form microfibrils, which in turn wrap around each other creating larger fibrils, providing the structural support for most tissues (Wenstrup *et al.* 1991).

Each chain contains approximately 1000 amino acids with glycine making up one third of these amino acids (Wenstrup *et al.* 1991). Other amino acids found in the collagen helix are proline, hydroxyproline (together contributing one fifth to one quarter), leucine and lysine (Ezzo 1994; Schwarcz and Schoeninger 1991). The amino acids are a mixture of indispensible (20%) and dispensible (80%). Indispensible amino acids are those which cannot be synthesised by the body and therefore must be consumed. Some dispensible amino acids are also considered to be 'conditionally indispensible' as they are crucial at certain periods of life, e.g. for rapid growth in infants, and can act like indispensible amino acids during synthesis at these times (Jim *et al.* 2006). There are only minor differences in the amino acid

composition of the two types of alpha chains, as can be seen in the composition of the two types in chick bone (Miller *et al.* 1967) is given in Table 4.1.

Elements that are present in collagen and can be utilised for isotopic analysis are carbon, nitrogen, sulphur, oxygen and hydrogen (Schwarcz and Schoeninger 1991; Lee-Thorp 2008).

Table 4.1Composition of alpha chains in chick bone (Miller et al. *1967). Values are the number of residues per 1000 total residues.*

Amino acid (dispensible) ***=Conditionally **i**ndispensible	**α1**	**α2**	**Amino acid (**indispensible**)**	**α1**	**α2**
3-Hydroxyproline	0.8	1.0	Threonine	19	18
4-Hydroxyproline	101	100	Valine	14	26
Aspartic acid	42	48	Methionine	8.6	5.4
Glutamic acid	78	65	Isoleucine	6.3	18
Alanine	128	104	Leucine	20	31
Hydroxylysine	5.5	8.2	Phenylalanine	14	14
Proline*	118	120	Lysine	29	24
Glycine*	332	330	Histidine	2.8	7.0
Tyrosine*	2.4	2.5			
Serine*	28	28			
Arginine*	49	50			

The remodelling rate of human bone, and therefore collagen, is not known for certain as the turnover rate is so long (Ezzo 1994), but it has been given variously as between 10-30 years (Ambrose 1993) and over 30 years (Stenhouse and Baxter 1979). The rate varies depending on the bone in question. Rummel and colleagues (2007) give the effective turnover rate (rather than absolute turnover rate) as six years for ribs, 33 years for femora and 50 years for the skull. Age and speed of growth will also affect the turnover of bones. Hedges *et al.* (2007) have shown that the turnover rate of midshaft femoral bone collagen is much higher in adolescence than adulthood and therefore an individual aged 35 years old can have as much as 50% of collagen that was synthesised prior to the age of 20 years old. External factors, such as diet and exercise will have additional effects on the turnover rate (Ambrose 1993; Ezzo 1994; Rummel *et al.* 2007). The relatively slow turnover in bones such as the femur and the skull means that any short-term variations will be averaged out (Chisholm 1989) whereas

in tissues with shorter turnover rates, e.g. ribs, dietary variation may have a greater effect on the isotopic values.

4.2.2 Structure and Composition of Skin

The skin is comprised of three layers - the epidermis, dermis and hypodermis (Haake *et al.* 2001). In most parts of the human body skin is no more than 2mm thick (Odland 1991). The epidermis is the outer layer of skin and is comprised of 90-95% keratinocytes, i.e. cells which synthesise keratin (Haake *et al.* 2001). Keratin plays a structural role in skin (Haake *et al.* 2001). The thickness of the epidermis varies between 75-150µm over most of the body and is thicker still on the palms and soles (Odland 1991). Melanocytes, which produce melanin, are also found in the epidermis (Haake *et al.* 2001). The epidermis is continually turning over and completely replaces itself in approximately two months (Odland 1991).

The dermis, the connective tissue part of skin, provides the skin's pliability, elasticity and strength, interacting with the epidermis to maintain the properties in both layers (Haake *et al.* 2001). It is the principal tissue of skin. At the scalp (where the 18 out of 19 of the samples in this study come from) it is approximately 1.3mm deep (Rushmer *et al.* 1966), i.e. in the region of 13 times thicker than the epidermis. Considerable variation is seen in the thickness of the dermis across the body (see Rushmer *et al.* 1966: fig. 1c) The dermis is comprised of two main types of fibrous connective tissue - collagen and elastic connective tissue - as well as non-fibrous connective tissues, salts, water and glycosaminproteoglycans (Haake *et al.* 2001; Odland 1991). The hypodermis is the innermost layer and is differentiated from the dermis by the transition from fibrous to adipose connective tissue (Haake *et al.* 2001). This layer insulates the body, serves as an energy reserve and protects the skin. It is well integrated through nerves and blood supply to the dermis. Hair follicles and sweat glands are found in the subcutaneous fat (Haake *et al.* 2001).

Approximately 75% of the dry weight of skin is collagen found in the dermis (Haake *et al.* 2001; Odland 1991) and of the proteins in skin, collagen makes up approximately 90% (Wenstrup *et al.* 1991). In adults, Type I collagen accounts for the greatest proportion - between 80-90% (Haake *et al.* 2001; Odland 1991; Wenstrup *et al.* 1991). Types III to VIII are all present in lesser amounts, with Type III the most abundant of these at 8-11% (Odland 1991; Wenstrup *et al.* 1991).

Type III collagen is comprised of three α1 chains and therefore has a slightly different composition to Type I collagen, which has two α1 and one α2 chain. It is predominant in foetal skin but its amount relative to Type I collagen declines from birth.

Differences in amino acid composition of the alpha chains have been shown to exist between species and different types of collagen, although it is not always clear which type has been analysed in the published studies (Bornstein and Piez 1964; Chung and Miller 1974; Francois and Glimcher 1967; Miller *et al.* 1967). There is no study that compares Types I and III collagen from skin to the collagen from bone from the same individual. Thus it is difficult to know the exact difference between them.

Table 4.2 The composition of alpha chains in skin and soft tissues of different species. Values given are residues per 1000 total residues.

	Francois and Glimcher (1967) Calf skin			**Chung and Miller (1974) Human soft tissues**	**Bornstein and Piez (1964) Human skin**	
Amino acid	**α1**	**α2**	**α3**	**α1(III)**	**α1**	**α2**
3-Hydroxyproline	1.7	1.3	1.5		0.8	0.9
4-Hydroxyproline	104	98	94	125	91	82
Aspartic acid	43.9	45.6	44.8	42	43	47
Threonine	18.7	18.9	18.5	13	16.5	19.2
Serine	36.3	34.4	36.6	39	36.8	35.1
Glutamic acid	76	69	77	71	77	68
Proline	124	112	124	107	135	120
Glycine	325	333	326	350	333	337
Alanine	118	107	119	96	115	105
Valine	14.9	26.0	16.4	14	20.5	33.3
Methionine	7.7	5.3	7.3	8	4.9	5.2
Isoleucine	8.2	13.7	8.9	13	6.6	14.8
Leucine	19.2	28.4	20.3	22	19.5	30.1
Tyrosine	3.8	3.2	3.4	3	2.1	4.6
Phenylalanine	11.8	13.2	11.9	8	12.3	11.7
Hydroxylysine	5.7	9.1	6.2	5	4.4	7.6
Lysine	30.9	24.1	29.9	30	30.0	21.6
Histidine	2.5	5.9	2.7	6	2.0	9.7
Arginine	47.2	51	51	46	50	51

The amino acids that are the most disparate between α1 and α2 chains in skin samples are 4-hydroxyproline, glutamic acid, alanine (all dispensible), proline (conditionally indispensible) and valine, isoleucine, leucine and lysine (all indispensible) (see Table 4.2).

The rate of human dermal collagen turnover is given as approximately 0.037% ±0.003% per hour (Babraj *et al.* 2005). Thus 100% turnover takes in the region of 112 days. El-Harake and colleagues (1998) found a slightly higher rate of turnover of 0.076%/h although a large standard deviation of ±0.063%/h means that this is not statistically different from the results of Babraj *et al.*'s (2005) study. At this higher rate, complete turnover would take only 55 days. El-Harake *et al.* (1998) note the possibility of dermal collagen turnover rates being affected by the anatomical location, which may have variations in the thickness of the skin.

4.2.3 Structure and Composition of Teeth

The anatomy of a tooth can be divided into a crown and a root. The core of the whole tooth is dentine, with enamel coating the crown and cement coating the root. Enamel is an inorganic tissue, whereas both dentine and cement have inorganic and organic components (Hillson 2002: 8). By weight dentine is composed of 70% inorganic material and 30% organic material and water (Aufderheide and Rodríguez-Martín 1998: 396). The collagen in the organic fraction of the dentine is Type I, the same as bone (Hillson 2002: 226).

Tooth formation begins with the crown. The enamel and predentine (unmineralised dentine) form in conjunction. As the enamel builds on the outside of the crown the dentine layers build up internally. Mineralisation of the dentine occurs shortly after the predentine is secreted. The pulp chamber, roots and canal are then formed, with secretion of predentine ending at the apex (Hillson 2002: 121).

Whilst the initiation of tooth formation is relatively predictable the completion of the crowns (and thus the dentine) is more variable (Hillson 2002: 125). Similarly the completion of root formation can take between two to four years for most teeth. The third molar is highly variable in terms of formation, which may initiate sometime between 7 and 13 years of age, with root completion usually between 17 years and the early twenties. Variation in formation is also seen between the sexes and to some degree between mandibular and maxillary teeth as illustrated in Table 4.3. The level of variation can be seen in the results of several studies that have investigated the stages of tooth formation (summarised in Table 4.3). These studies used radiographs in order to assess the tooth formation, but enamel and dentine are only visible on radiographs when they are mineralised sufficiently to create radio-opacity. In the initial

formation of these tissues, they are a poorly mineralised matrix and as such undetectable radiographically. Thus the timing for the formation of the permanent molars is slightly delayed. For the purposes of this research an exact time of formation is not needed, as the dentine will represent an average dietary signal over the duration of its formation and therefore an age range will suffice.

*Table 4.3 Formation of the permanent molars. All ages given in years. Those with an * apply to both upper and lower jaws. Those with a † indicate a mean age from upper and lower observations. Those with a ˆ are from the lower jaw only. Those in bold are an average of male and female. Ci= Initial cusp formation; Crc= Crown complete; Ac= Apical closure complete.*

	1st Molar			**2nd Molar**			**3rd Molar**		
Reference	**Ci**	**Crc**	**Ac**	**Ci**	**Crc**	**Ac**	**Ci**	**Crc**	**Ac**
Schour and Massler (1940)	0.0*	2.5-3.0*	9.0-10.0*	2.5-3.0*	7.0-8.0*	14.0-16.0*	7.0-10.0*	12.0-16.0*	18.0-25.0*
Smith (1991: Tables 7 & 8)	**0.0ˆ**	**2.2ˆ**	**9.1ˆ**	**3.6ˆ**	**6.4ˆ**	**14.8ˆ**	**9.5ˆ**	**12.2ˆ**	**20.4ˆ**
Fanning and Brown (1971)	**0.1-0.3ˆ**	**2.0-3.1ˆ**	**7.8-12.0ˆ**	**2.8-5.5ˆ**	**5.8-8.5ˆ**	**12.4-17.5ˆ**	**7.4-11.9ˆ**	**10.5-16.5ˆ**	**17.1-21.4ˆ**
Anderson *et al.* (1976)		3.8†	**9.6†**	**3.8†**	**6.5†**	**14.2†**	**9.4†**	**13.0†**	**18.5†**
Haavikko (1970)		**3.5†**	**9.5†**	**3.8†**	**7.2†**	**15.4†**	**9.5†**	**13.3†**	**20.1†**

The root dentine from the molars, which is used in this research, is therefore primarily laid down between the ages of approximately 2.5-10 years (M1), 6-15 years (M2), and 12-20 years (M3).

The roots are covered by a layer of dental cement, which is lain down throughout life as a response to the changing mechanical forces exerted on the tooth (Hillson 2002: 198). The thickness of the layer of cement can vary from 100-600 µm in an adult tooth and in children it can be as little as 10µm. It contains about 25% organic material, which is almost entirely made up of collagen. It is often poorly preserved in archaeological material and can show similar diagenetic alteration to dentine (Hillson 2002: 206). However, given the thinness of the cement it is unlikely to affect the isotopic composition significantly.

After complete tooth formation secondary dentine can be lain down in the teeth as a result of age or attrition. Age related secondary dentine is formed in the root. If the occlusal surface, i.e. enamel, is worn down and primary dentine is exposed, reparatory secondary dentine is lain down in order to protect the pulp chamber of the tooth. This type of secondary dentine generally occupies as larger volume than the age related secondary dentine and it is likely to be found in the crown of the tooth, although it can also form in response to the penetration of cement (Hillson 2002: 194).

4.2.4 Structure and Composition of Hair

The excellent chronological resolution that individual hair fibres provide are due to their unique biology (Wilson *et al.* 2007). Saitoh *et al.* (1969) measured hair growth on the vertex of the scalp to be on average 0.44mm/24h for men and 0.45mm/24h for women, and for the temporal area in men the rate was 0.39mm/24h. Rate of growth varies slightly on different parts of the scalp, ranging from 0.30mm/24h on the frontal and temporal to 0.35mm/24h on the crown and above the ear (Barman *et al.* 1964; Myers and Hamilton 1951). This rate is generally taken as a constant, and averaged to 0.35mm a day or 1cm a month although it is known to increase slightly during spring and summer, and during pregnancy and adolescence (O'Connell 2005; Saitoh *et al.* 1969; Wilson and Gilbert 2007). Hair fibres do not undergo any biogenic change and therefore are a snap-shot of individuals' physiology and chemistry at time of hair growth (Tobin 2005; Wilson *et al.* 2007; Wilson and Gilbert 2007).

Scalp hair has three phases of growth, which are cyclical in nature. Anagen is the growth phase of the hair, lasting anything from three years onwards (Myers and Hamilton 1951). This is followed by a short transitional phase – catagen – lasting one to two weeks (Freinkel 2001; Tobin 2005; Valkovíc 1977). During catagen the base of the hair constricts and becomes keratinised, forming a colourless club root, in preparation for shedding of the hair (Williams *et al.* 2011). The final resting phase is telogen, which lasts approximately three to four months after which the hair fibre is shed (Freinkel 2001; Tobin 2005; Valkovíc 1977). Regeneration rates (i.e. time between shedding of hair and first appearance of new hair) for hairs on the crown range between 110 and 147 days and were observed to be quicker in males than in females, yet females had hairs that grew for the longest time length (Myers and Hamilton 1951). The mean regeneration time for scalp hairs was 129 days and the rate was fairly consistent between age groups from 9-84 years old (Myers and Hamilton 1951). About 85% of the hair of an adult are in the anagen phase at any one time, with 15% in telogen (Freinkel 2001; Williams *et al.* 2011). The average number of scalp hairs is 100,000 and the

density of hair follicles decreases with age as the head grows and skin is stretched (Freinkel 2001). The average number of hairs in catagen is 1% (Williams *et al.* 2011).

Hormones can influence the activity of hair follicles in a number of ways, including the duration of the anagen and catagen phases and the rate of growth (Ebling *et al.* 1991). Fluctuations in the number of hairs in the telogen phase have been observed for individuals in temperate Europe over a number of years. One study has shown that maximum telogen percentage occurred in late summer and early autumn and a minimum occurred in winter (Courtois *et al.* 1996). Similar results were found by Randall and Ebling (1991), with August/September being the peak for hair loss and March the minimum. It has been demonstrated that for individuals under physiological stress at the time of death, the percentage of hairs in telogen was higher (>15%) than for normal individuals (Williams *et al.* 2011).

The knowledge of these phases is important as ideally only anagen hairs should be selected for analysis. During the telogen phase, hair is not growing and therefore the isotopic signal in these hairs will be between 0-3 months behind in reflecting the diet (O'Connell and Hedges 1999a). Fortunately, the human scalp has about 100,000 hairs, 85% at any given time being in anagen (Valkovíc 1977). Hair growth is asynchronous, probably due to the variation in anagen and telogen lengths between hairs, so that in any given area on the scalp the hairs are in a mosaic pattern of stages of the growth cycle (Freinkel 2001).

The growth cycle of hair also impacts on the isotopic signal of the hair. The error associated with asynchronous growth cycles of hairs has been investigated for archaeological populations by Williams and colleagues (2011). The mean difference in the isotopic values of anagen hairs compared to mixed phase hairs was 0.2 ±0.3‰ for carbon and 0.5 ±0.5‰ for nitrogen (including both individuals with normal levels, n=5, and high levels, n=5, of telogen) (Williams *et al.* 2011). These differences are not statistically significant and well within the range of environmental variation and in the case of carbon acceptable machine error. Therefore I do not consider that the growth cycle error will have a significant impact on the trends investigated in connection with seasonal diets as the variation in the hair is much larger than that caused by the growth cycle error.

Hair formation occurs in the bulb of the hair follicle during anagen. The cell division which creates new cells occurs without diurnal variation (Freinkel 2001). By weight hair is comprised of 65-95% keratin proteins, with the remainder being made up of intercellular

membranes, the cuticle and the medulla (Gillespie 1991; Wilson and Gilbert 2007). The diameter of scalp hair can vary between 40-120µm but averages around 70µm (Freinkel 2001). The cuticle of the hair, i.e. the outermost layer, is comprised of five to ten layers of flat overlapping scales, or squames, which contain the sulphur-rich proteins (Freinkel 2001). Beneath the cuticle is the cortex, which contains bundles of keratin fibres and trichohyalin granules, whose function is thought to be to aggregate the keratin fibres together (Freinkel 2001). Within the cortex is the medulla, although it is not present in all hairs. Colour is imparted into the hair shaft by dendritic melanocytes, which are located in the bulb (Freinkel 2001). The keratins in the cortex are the main source of protein in a hair shaft. Due to the insolubility of the proteins, the structure of keratin has not been well established, and their configuration is only partially thought to be helical (Freinkel 2001). The sulphur-rich proteins in the hair shaft provide stability in the keratins through disulfide bonding (Freinkel 2001).

The elements present in hair that can be utilised for isotopic analysis are carbon, nitrogen, sulphur, oxygen and hydrogen (O'Connell 2005; Wilson and Gilbert 2007). These are present in hair at similar or higher levels compared to other body tissues (O'Connell 2005).

A shift in dietary resources has been shown to take only a few days to reflect in the isotopic values of the keratin (Ayliffe *et al.* 2004; Nakamura *et al.* 1982). Full isotopic equilibrium has been shown to take several months in horses, although the rate of isotopic change does vary according to the type of dietary transition taking place (Ayliffe *et al.* 2004). West *et al.* (2004) showed that extremely short dietary changes can be detected in horse hair given the right sampling procedures and therefore the limiting factor in the resolution obtained is analytical rather than biological. However, this appears to be species specific as short (<1 week) dietary switches in cattle only elicited a weak isotopic change (Schwertl *et al.* 2003). Isotopic equilibrium in human hair has been shown to take much longer - up to one year in an adult female - with carbon taking longer than nitrogen to reach equilibrium (O'Connell and Hedges 1999a). Therefore the slower adjustment may restrict researchers' ability to identify short dietary changes isotopically in humans. Due to the long equilibrium times the true dietary isotopic value may not be reached by the hair in a seasonal cycle of dietary change (Ayliffe *et al.* 2004; Zazzo *et al.* 2008). In other words, the magnitude of variation seen in hair for a six months seasonal dietary signal may be less than the actual difference between the two diets, nonetheless a change should be identifiable. This has been shown for horses and is due to the existence of multiple pools from which the keratin is synthesised that have different turnover rates. Three pools have been proposed, one with a very fast turnover rate

($t_{1/2}$=0.5 days), one intermediate ($t_{1/2}$=4.3 days) and one very slow ($t_{1/2}$=136 days). These pools contribute to the synthesis of new tissues in different amounts and their isotopic differences due to the different turnovers create a signal that dampens the true dietary signal (Ayliffe *et al.* 2004).

4.3 From Consumption to Consumer's Tissues

In order to interpret isotopic values derived from human tissues it is imperative to know how the dietary constituents (e.g. protein, carbohydrate) contributed to the synthesis of those tissues. In general the isotopic composition of carbon and nitrogen incorporated into the collagen and keratin of the consumer will be representative of the carbon isotopic composition of the protein portion of its diet (DeNiro and Epstein 1978a; Schoeller 1999; Sealy 2001; Sillen *et al.* 1989). However, the quality of the individual's diet will affect the synthesis of the tissues (Sillen *et al.* 1989; Tieszen and Fagre 1993b).

4.3.1 Routing in Collagen

Carbon

Controlled animal feeding experiments have shown the carbon isotopic values of bone collagen to be related to the isotopic value of protein in the diet (Ambrose and Norr 1993; Jim *et al.* 2004; Tieszen and Fagre 1993b), although recent research has suggested that up to one quarter of the $\delta^{13}C$ value of bone collagen is due to the contributions from the carbohydrate and lipid components of the diet (Fernandes *et al.* 2012). On mono-isotopic diets the isotopic values of the collagen are predictable and relatively easy to work out as long as the probable food sources are known (e.g. Tykot *et al.* 2009). This is often quoted as +5‰ higher than the diet and is supported by experimental evidence (Ambrose 2000; Ambrose and Norr 1993; Froehle *et al.* 2010; Howland *et al.* 2003; Jim *et al.* 2004; Jim *et al.* 2006; Krueger and Sullivan 1984; Tieszen and Fagre 1993b; Vogel 1978). However, this is only true when both the protein and non-protein portions of the diet have the same $\delta^{13}C$ value (Ambrose *et al.* 1997). In diets where the sources is wholly C_3 or C_4, the $\Delta^{13}C_{d\text{-}co}$ varies less, with C_3 resulting in a difference of 1.4‰ to 3.7‰ and C_4 3‰ (Hare *et al.* 1991; Tieszen and Fagre 1993b).

Feeding experiments that have varied proportions of C_3 and C_4 protein and energy sources have shown that there is a non-linear relationship between the $\delta^{13}C_{coll}$ and percentage of C_3

protein to C_4 energy and vice versa (Ambrose and Norr 1993; Jim *et al.* 2006). The extent of the shift towards pure C_3 or C_4 end members varies with the percentage of protein in the diet, with for example 5% C_3 protein/95% C_4 energy causing a 42% shift to a pure C_3 end-member; 20% C_3 protein/80% C_4 energy causing a 66% shift to a pure C_3 end-member and 70% of C_3 protein/30% C_4 energy causing a 95% shift to a pure C_3 end-member (Ambrose and Norr 1993), with similar magnitudes of difference found in other studies (Ambrose and Norr 1993; Froehle *et al.* 2010; Howland *et al.* 2003; Jim *et al.* 2004; Tieszen and Fagre 1993b). The dietary protein is therefore seen to be preferentially routed to the collagen. This discrepancy of about 6‰ from the pure end members represents the contribution of dietary energy macronutrient carbon to the synthesis of collagen (Ambrose and Norr 1993; Jim *et al.* 2006; Tieszen and Fagre 1993b).

This issue has been investigated further by analysis of the individual amino acids in the diet and subsequently in the bone collagen. The indispensible amino acids have an average of six carbon atoms per molecules whereas the dispensible amino acids glycine and valine, which comprise approximate 45% of collagen, have only two and three carbon atoms respectively (Ambrose and Norr 1993). The bulk $\delta^{13}C$ values of collagen will therefore be a weighted average of these values in each constituent amino acid (Schwarcz 2000).

The indispensible amino acids must be derived from dietary protein as they cannot be synthesised, whereas the dispensible amino acids can be synthesised from either dietary protein, carbohydrate or fat (Ambrose and Norr 1993; Sillen *et al.* 1989). Indispensible amino acids are routed from the diet into collagen and do not fractionate when they ascend the food chain whereas the kinetic processes involved in synthesising dispensible amino acids causes fractionation of carbon isotopes (Hare *et al.* 1991; Jim *et al.* 2006; Schwarcz 2000). Similarly 'conditionally indispensible' amino acids, such as proline, which is required for growth, have been shown to act like indispensible amino acids being directly routed from the diet to bone collagen (Jim *et al.* 2006) and thus do not fractionate.

The range of offsets between $\delta^{13}C_{diet}$ and $\delta^{13}C_{coll}$ in experimental studies has been explained by the amount of routing of amino acids from the diet directly into the bone collagen. When an excess level of each amino acids is supplied in the diet (i.e. more than enough for net growth and tissue turnover) more routing of indispensible and dispensible amino acids occurs as this is more energy efficient than synthesis of dispensible amino acids (Jim *et al.* 2006; Schwarcz 2000). This is thought to occur when protein levels are >12% in rats (Jim *et al.*

2006). The maximum amount of routing that can be expected has been proposed as 65% (Ambrose *et al.* 1997) and controlled feeding experiments have observed values of approximately 52-57% in both rats and swine (Ambrose and Norr 1993; Froehle *et al.* 2010; Jim *et al.* 2006). At low levels of protein, then, there will be more synthesis of dispensible amino acids and as such there will be a greater disparity between the values of indispensible amino acids and dispensible amino acids in bone collagen than is seen in the diet (Jim *et al.* 2006). Hare *et al.* (1991) showed that the enrichment between the diet and collagen can be explained by the enrichment in certain dispensible amino acids - glycine, glutamate and aspartate. In a feeding study using pigs, Howland *et al.* (2003) found that the $\delta^{13}C$ values of the dispensible amino acids were enriched from the diet to varying degrees.

One important issue, then, for interpreting bulk collagen values is whether the individual consumed an adequate level of protein. In high protein cases low protein foods will be underrepresented in the bulk collagen values, whereas in low protein diets carbohydrates and fats will contribute more to the bulk collagen value.

In the case of low protein diets, where scrambling of carbon takes place, minor contributions (i.e. 20-30%) of marine foods in an otherwise terrestrial diet will theoretically show little difference in $\delta^{13}C$ values compared to solely terrestrial diets with no marine contribution (Hedges 2004). High protein diets, conversely, will be sensitive to minor quantities of marine protein.

Nitrogen

Understanding of how nitrogen is routed into tissues and how it is affected by the dietary constituents is not well understood (Hedges and Reynard 2007). Very few tightly controlled feeding studies have been carried out on any animal and most of the data come from non-humans.

Different tissues will differ in terms of $\delta^{15}N$ values compared to the diet, for example, observed enrichment values range from -0.5‰ to +9.2‰ for different tissues from different species under different feeding regimes (DeNiro 1987; DeNiro and Epstein 1981; Minagawa and Wada 1984; Schoeninger and DeNiro 1984; Schwarcz 1991; Sponheimer *et al.* 2003a). Variation has also been seen among members of one trophic level. Several explanations have been forwarded including variation in plant $\delta^{15}N$, gut physiology of herbivores, protein quality of the diet consumed, and the animal not being in a steady physiological state, e.g.

under thermal stress, during growth or pregnancy, and behavioural factors, e.g. food preferences (Sponheimer *et al.* 2003a; Sponheimer *et al.* 2003b; van Klinken *et al.* 2000).

The enrichment between diet and collagen in the literature varies between 2.2‰ and 3.9‰ (Ambrose 2000; DeNiro and Epstein 1981; Hare *et al.* 1991; Mizutani *et al.* 1991). A mean value of 2.75‰ for diet-animal $\delta^{15}N$ values has been proposed, although this has been shown to vary widely depending on diet of the animal, trophic level, physiological state of the animal and trophic level (Caut *et al.* 2009). A standard faunal-human $\delta^{15}N$ value of 3-5‰ is often used (Bocherens and Drucker 2003) and based on archaeological values this seems to work well for at least establishing plant versus meat protein consumption (Hedges and Reynard 2007). However, recent work has challenged this value as being too low and therefore overestimates the amount of animal protein thought to have been consumed in the past (O'Connell *et al.* 2012). Through a combination of data from humans on controlled diets and data from free living trials, the value between diet-collagen in humans has been estimated as falling between 5.9‰ and 6.3‰ (O'Connell *et al.* 2012). The authors note that this may be an overestimation in itself and they suggest the more conservative value of 4.6‰, which still falls at the higher end of the figure of 3-5‰ used in most isotope studies. This reiterates the problem discussed by Hedges and Reynard (2007) of how the collagen isotope value translates to the actual amount of animal protein sources in the diet and thus dietary reconstruction can be problematic. Additionally, by altering the model of how nitrogen values transcend trophic levels by relatively small amounts, the conclusion of the proportion of protein in the diet changes to a significant extent (Hedges and Reynard 2007). Thus it is clear that the relationship between diet and collagen isotope values in humans is uncertain. However, as we often deal with spreads of data points for both faunal and human samples, using a range of 3-5‰ is still useful for identifying the consumption of animal protein; it is defining the limits of the values to be taken as indicative of animal protein diets which remains problematic (Bocherens and Drucker 2003).

4.3.2 Routing in Keratin

There is a strong correlation between carbon, nitrogen and sulphur isotopic values of dietary protein and those of hair keratin as well as other body tissues (González-Martín *et al.* 2001; O'Connell 2005; O'Connell and Hedges 1999b; O'Connell *et al.* 2001; Peterson *et al.* 1985) as demonstrated in controlled feeding experiments (Ambrose 2000; DeNiro and Epstein 1978b; Sponheimer *et al.* 2003a). As with collagen, protein $\delta^{13}C$ values in the diet are a good predictor of keratin $\delta^{13}C$ values from hair (Tieszen and Fagre 1993b). Mechanisms

responsible for the routing and synthesise of amino acids in keratin are the same as collagen, although the enrichment between diet and keratin is smaller than that of diet and collagen due to the different amino acid composition of the two tissues (Tieszen and Fagre 1993b; Vogel 1978). This has been demonstrated in both human and animal feeding studies (controlled and observed), with the carbon enrichment between diet and keratin ranging between 0.6‰ and 3.6‰ (Caut *et al.* 2009; DeNiro and Epstein 1978b; Mizutani *et al.* 1991; Tieszen and Fagre 1993b; Yoshinaga *et al.* 1996). The enrichment between diet and keratin for nitrogen has shown greater variation - between 2.8‰ and 6.4‰ - possibly due to the manipulation of controlled diets to investigate high versus low proteins (Ambrose 2000; Mizutani *et al.* 1991; Sponheimer *et al.* 2003a; Yoshinaga *et al.* 1996) but also probably in part due to the differences in species diet, trophic level and physiological state of the animal (Caut *et al.* 2009). A controlled dietary study on humans has calculated the diet-keratin offset to be between 5.0‰ and 5.3‰. However, this relies on small sample sizes and compounds the errors associated with multiple studies (inaccurate representation of the population, representation of diet in tissue analysed etc).

4.4 Potential Limitations

This research uses dietary reconstruction to explore social differences. However, there are some potential problems with this. Firstly, food may not be used as a tool for defining social or political identity or status and therefore diet may be homogeneous even in the most stratified group. Secondly, if food is used as a mechanism to reinforce social differences it may be done in such a way that is isotopically invisible in the archaeological record. If the types of meat from one trophic level are used to mark status rather than amount of meat or meats from animals belonging to different trophic levels, then this may not be isotopically detectable. For example, different cuts of meat (e.g. fillet versus stewing steak) or the meat from different types of herbivores such as llamas or guinea pigs may have different social values but be isotopically identical. Likewise if one food substance is prepared in different ways depending on social status, e.g. roasting versus boiling, this will not be identifiable. Primary and secondary animal products are also isotopically indistinguishable, although this is of minimal concern in South America as secondary products, e.g. blood or eggs, are unlikely to contribute significantly to the diet. Carbon isotopes can only distinguish plants into broad categories (C_3, C_4, CAM) and therefore if there is social differentiation using plants within the same category, e.g. potatoes versus beans, this will not be identifiable either.

However, given the wide isotopic range of possible food resources in the lower Ica Valley, i.e. marine, freshwater, terrestrial animals and plants, there is enough variability in both food choices and isotopic signatures for the use of food as a social tool to be visible.

4.5 Potential Problems with Diagenesis

Unless diagenetic change has occurred then the stable isotope ratio of body tissues of deceased individuals should not change over time and therefore it can be used to reconstruct diets (Ambrose 1993). Some studies have used extensive methods to rule out diagenetic change in their bone samples (e.g. Schutkowski *et al.* 1999) illustrating collagen's resistance to post-mortem diagenetic change of stable isotopes (Ambrose 1993; Chisholm 1989). Other studies have elected to use tissues such as tooth enamel that are less susceptible to diagenetic change (e.g. Sponheimer and Lee-Thorp 2006).

Proteins can be degraded by several different mechanisms. Hydrolysis, the most common type of protein degradation, causes fragmentation of the protein molecule. Water, needed for hydrolysis, can be introduced during decay of the body or by environmental agents (Aufderheide 2003: 288). Denaturing of proteins, which cause a change in its structure, can be caused by heat, strong pHs and UV light (Aufderheide 2003: 289; Sionkowska 2006). Consequently the proteins are more susceptible to hydrolysis (Aufderheide 2003: 289). However, desiccation retards protein degradation (Aufderheide 2003: 292) and thus it should be a minimal problem in this research.

The burial environment is influential on the level of diagenetic change sustained by bone (Sandford 1993; Sponheimer and Lee-Thorp 2006). As the amount of the organic phase of the bone and its integrity decrease during its interment, the mineral component becomes more exposed and susceptible to diagenesis (Schutkowski *et al.* 1999). This rate of degradation and resulting diagenesis is reliant on too many variables to make it quantifiable. A basic measure of the integrity of the bone samples and other types of collagen is the atomic C:N ratio. The C:N ratio as estimated from its amino acid composition should be 3.21 (Ambrose 1993). The accepted range for uncontaminated samples is 2.9-3.6 (DeNiro 1985), although this is not agreed upon by all, with Ambrose (1993) for example, labelling samples with ratios between 3.4-3.6 as having suffered some contamination. A C:N ratio within the acceptable range does not necessarily mean that it has not been altered diagenetically (DeNiro 1985). In order to comprehensively rule out any alteration the amino acid composition or the presence of intact

proteins should be assessed (Schwarcz and Schoeninger 1991). In fresh, modern bone the amount of collagen is 22% by weight, with the value decreasing steadily during burial (van Klinken 1999). Below approximately 1% the samples is considered unsuitable for analysis (van Klinken 1999).

Ancient desiccated skin from naturally mummified Nubian individuals has been shown to have a similar amino acid composition and structure to modern skin due to the retardation of microbiological decay and leeching of organic components in the arid burial environment (Flannery *et al.* 1999; Michelin Lausarot *et al.* 1972). The removal of the water in the skin makes desiccated samples rigid and appear compressed as the collagen fibres are no longer in a swollen and flexible state (Flannery *et al.* 1999).

Dentine and dental cement are very similar to bone in terms of biochemical composition and therefore will be affected diagenetically in similar ways (Beeley and Lunt 1980). The collagen in the dentine can be degraded causing a softening of the tooth, especially the roots, making it more susceptible to physical damage (Beeley and Lunt 1980). Dentine can be affected diagenetically by mycelium, which tunnels into the teeth and destroys the collagen (Poole and Tratman 1978). The archaeological age of the tooth does not correlate with the amount of diagenetic change that the specimen undergoes (Falin 1961; Sognnaes 1956).

Hair is physically and chemically stable with respect to stable isotopes (O'Connell 2005). There are few things that degrade keratin, and hair is known to survive in the archaeological record in more than just isolated incidents (Wilson *et al.* 2001). The main agents responsible for its degradation are keratinolytic fungi, micro-organisms and insects (Böckle *et al.* 1995; DeGaetano *et al.* 1992; Wilson 2008). Like bone, the C:N ratio and amino acid composition can be used to assess the level of alteration due to diagenesis. This type of assessment has been applied to hair from varying time periods (e.g. 1000 BP and 3200 BP) and from varying geographical areas (e.g. Egypt and an Alpine glacier) and showed that the hair in all cases was preserved to a relatively good degree (Macko *et al.* 1999a; Macko *et al.* 1999b). Where only C:N ratios are assessed in hair samples the value should be within the range for modern hair samples of 3.0-3.8 (O'Connell and Hedges 1999a).

4.6 Scientific Background Summary

In summary, stable carbon and nitrogen isotopes enable reconstruction of the broad category of plants consumed and the trophic level of the individual. Due to the way in which collagen and keratin are synthesised and the macronutrients routed, the protein portion of the diet will have contributed to the observed isotope signal more than other dietary components, such as carbohydrates or fats. The four different tissues are all synthesised at different rates and will reflect diet from childhood (tooth dentine), through to an adult average (bone collagen) and towards the final months of life (skin collagen and hair keratin). There is the potential for diagenetic alteration of these tissues but these can be minimised by careful sampling and the sample quality checked in several ways.

Chapter 5 Materials and Methods

This chapter describes the human, faunal and plant samples taken and analysed for this research. It explains how the human and faunal remains used in this research were collected from the looted cemeteries, and the osteological methods used to assess and estimate the sex and age of the human individuals. The manner in which subsamples were taken is given for the four different tissues and a summary of the human and faunal samples taken is presented. Details of the archaeological plant remains, from excavations carried out in 2007 in Samaca and Ullujaya, that were sampled for this thesis are also given. The second half of this chapter describes the extraction and analytical methods used for all the samples taken.

5.1 Methods used to Collect Human and Faunal Samples

The human and faunal remains chosen for analysis were all surface finds, as required by the fieldwork permits issued by the Instituto Nacional de Cultura del Perú (Ministerio de Cultura del Perú). Each of the seven cemeteries was systematically fieldwalked in transects located approximately two metres apart. At each instance of potentially useable human or faunal remains found, the location was recorded with a handheld GPS and the area flagged. Once the cemeteries had been surveyed in this fashion each location was revisited and the samples assessed for their potential usability. As well as visible physical deterioration caused by the wind and sun, ultra-violet light also degrades the proteins in tissues (Chang *et al.* 2005; Sionkowska 2006; Wilson *et al.* 2007) therefore limiting their potential for isotopic analysis of the organic component. In order to minimise this effect, remains that were partially buried under the surface of the sand were targeted for sample collection. In many instances, the unburied part of the remains had sustained little visible degradation by the external environment, evident by the difference in coloration and robustness of the bone (Figure 5.1). In some cases, remains had been repeatedly looted and therefore the buried portion was also partially sun and wind damaged.

In the cases of human remains, crania were targeted for sample collection for three reasons: 1) accidental sampling of the same individual for the same tissue more than once was not possible; 2) age and sex assessment could be performed giving context to the remains; and 3) four different tissue types were potential available from each individual (bone, tooth, skin and hair). Where sufficient crania were not available for sampling (particularly in Cemetery 734)

sampling focused on one type of long bone, for example right femora, in order to avoid repeated sampling of one individual. Obviously in these cases, age and sex information could not be assessed and multiple tissue types were not possible to collect.

Figure 5.1 Examples of the level of preservation seen in the human remains. Photographs by author.

The presence of animal remains in the cemeteries was low and therefore all suitable remains were sampled regardless of element present (Figure 5.2). Where wool or teeth were present along with bone both tissue types were taken unless one was obviously badly degraded. Identification of species was made in Cambridge with the use of photos and the sub-sample of bone taken for analysis.

Figure 5.2 Examples of well preserved animal remains. Photographs by author.

After location (GPS), osteological and palaeopathological information were recorded and photographs were taken (all in the field), tissue samples were taken in the field in the following manner for both human and animal samples:

Bone: small, circa 2.5cm^2, pieces of bone were cut using a Dremel drill. Preferentially thick cortical bone was taken, e.g. around nuchal crest of the skull.

Skin: small, circa 2.5cm^2, piece of skin was cut using a scalpel and blade. Where hair was also sampled, the skin was usually taken from the area from which the hair had been cut.

Teeth: Molars were preferentially taken from human remains and the best preserved tooth from faunal remains. Teeth were removed by a combination of leverage of the tooth, cutting the bone surrounding the socket and reliance on post-mortem damage to the bone.

Hair: The longest and least sun damaged hair was identified on the cranium. Approximately 50 hairs were selected and cut with a scalpel and blade as close to the scalp as possible. The proximal (root) end of the hair was taped with micropore tape in order to identify the ends in the laboratory. In the case of animal wool the root was not taped as the specimens taken were very short (<5cm).

Three individuals sampled (two from Cemetery 1004 and one from 734) were found to be in extremely good condition, with the bodies completely or almost completely articulated. Due to the level of preservation it was decided to carefully take samples without causing undue damage as further and more controlled study of these individuals is warranted, although not as part of this research. This resulted in not all of the tissues being sampled, for example teeth where the jaws were fully articulated.

5.2 Methods used in Osteological and Palaeopathological Analysis

In order to give the looted human remains a context in which to interpret the isotopic results, sex and age were assessed where possible for each individual. Adult remains were preferentially selected to avoid complications in interpreting isotopic results associated with breast fed infants (Fuller *et al.* 2006; Katzenberg *et al.* 1996). Roughly equal proportions of males and females were aimed for but this was not possible in every case due to the limited remains available. However, the numbers attained are enough to allow a statistically

meaningful comparison of the isotopic results. A demographic reconstruction of the cemeteries is not possible due to their incomplete nature (Alesan *et al.* 1999).

Recording sheets for the human remains were used in order to ensure each of the individuals was assessed in the same manner. Depending on the skeletal element used and the age of the individual (adult or juvenile), different recording sheets were available in order to provide the correct prompts for the aging and sexing method that was applicable (see Appendix 1 for examples of the sheets). The aging and sex methods employed are detailed in the following sections.

5.2.1 Determination of Sex

A range of sexing methods were used depending on the bones available for study and whether they were adult or juvenile remains. For the majority of specimens, crania were sampled and therefore the sexing methods used were those proposed by Bass (1995) and Buikstra and Ubelaker (1994), which are based on the morphological characteristics of the skull.

The morphology of the pelvis is regarded as being the most reliable sex determinate as the function of the pelvis is sex specific (Bruzek 2002; Buikstra and Ubelaker 1994). Methods such as Phenice (1969) have been shown to have very high accuracies, and these have been incorporated by the authors of the methods used here. The areas used for sexing ossa coxae are those given by Bass (1995) and Buikstra and Ubelaker (1994) and again rely on morphological differences. Metric assessment of sex (e.g. Bass 1995; Giles and Elliot 1963) was not used as the conditions of working in the field meant this was not practical. The existing metric techniques were also based on populations of European descent and therefore are unsuitable to apply to these South American populations (Buikstra and Ubelaker 1994).

Whilst morphological techniques have been developed for sexing juvenile remains (e.g. Schutkowski 1993) the accuracy of such methods in questionable and the difficulty in sexing juvenile skeletal material remains a problem (Scheuer and Black 2004:19). Any juvenile remains used in this research therefore have not been sexed.

5.2.2 Estimation of Age

A range of aging methods were used depending on the bones available for study and whether they were adult or juvenile remains. Where possible a multi-factorial approach for aging adults was taken as these have been shown to produce the most reliable age estimates,

whereas individual aging methods have had results of varying accuracy (Bedford *et al.* 1993; Lovejoy *et al.* 1985a; White and Folkens 2000). It has been shown that the methods chosen should factor in the population used for the creation of this method as there is a certain degree of genetic influence and lifestyle factors on the markers assessed. The majority of methods have only been developed based on one population and on some cases the reliability of the technique has then been tested on the same population (e.g. Kaur and Jit 1990; Lovejoy *et al.* 1985b; Meindl and Lovejoy 1985). Therefore to mitigate any bias in the techniques caused by these issues, techniques using populations native to the Americas were used where possible.

For individuals represented by crania, dental wear and cranial suture closure were the two methods of aging used. In the case of dental wear for age assessment, Lovejoy's (1985) method was preferentially used as is based on native Americans as opposed to Brothwell's (1981) based on early British populations (e.g. Iron Age). Cranial suture closure (Meindl and Lovejoy 1985) was the other method of aging crania used. This technique has been demonstrated as having varying degrees of accuracy depending on the sutures available for use (Hershkovitz *et al.* 1997; Meindl and Lovejoy 1985) whereas the dental aging is considered to be reliable (Lovejoy *et al.* 1985a). Therefore final age estimation using these two techniques was weighted towards that produced by the dental wear.

For individuals where crania were not present, a variety of aging techniques were used based on the elements available for study. These included changes to the pelvic bones – auricular surface (Brooks and Suchey 1990; Buckberry and Chamberlain 2002; Lovejoy *et al.* 1985b) and pubic symphysis (Brooks and Suchey 1990) – both of which are considered amongst the most reliable techniques due to the minimal movement and thus reduced possibility of non-age related changes to the area (Cox and Mays 2000; Stout 1992). Changes to the sternal rib ends (İşcan and Loth 1986) were also another technique used when ribs were present. This method was developed using the fourth rib, but research by Dudar (1993) has shown that the method is reliable for all of the mid ribs.

For juveniles, age was assessed primarily using dental eruption stages (Ubelaker 1989). Estimating juvenile age by dental development is considered to be the most reliable method as it is less affected by adverse environmental and physiological conditions than bone growth and fusion (Scheuer and Black 2000:12). Long bone length or epiphyseal fusion (Scheuer and Black 2000) were used where dentition was not present or other elements were also available for study. These are known to be affected by environmental and physiological factors, in

some cases significantly, and as such may produce inaccurate ages (Garn *et al.* 1973; Lewis and Garn 1960). However, it was necessary to use this technique because of the looted nature of the material and hence lack of any other skeletal features that could be aged.

5.2.3 Palaeopathological Observations

Palaeopathological observations were recorded for all individuals where appropriate. Descriptions were made in the field using standard notations, and identification of pathologies was made with reference to palaeopathological texts (Aufderheide and Rodríguez-Martín 1998; Ortner and Putschar 1981). Due to the difficulty of diagnosing pathologies from incomplete skeletons not all of the observations made could be related to specific illnesses.

5.3 Samples Collected

In total 111 bone, 70 tooth, 60 hair and 19 skin samples were taken from 120 individuals. Thirteen individuals had all four tissue types sampled, 35 had three tissue types sampled, 33 two tissues and 39 just one tissue type. The number of samples varied between cemeteries as did the types of tissues that were well enough preserved to sample (Table 5.1).

Table 5.1 Breakdown of the total number of individuals and the types of samples taken from each cemetery.

Cemetery	**1001**	**1002**	**1004**	**734**	**398**	**755**	**1003**
Total no. of individuals	**8**	**11**	**14**	**19**	**19**	**21**	**28**
No. of bone samples	6	10	14	18	18	19	26
No. of tooth samples	3	2	3	6	17	18	21
No. of skin samples	0	1	0	0	4	4	10
No. of hair samples	4	1	3	4	16	12	20

The majority of the bone sampled originated from the skull, although a number of different elements were sampled (Table 5.2). The varying levels of the different elements are a reflection of the differing levels of preservation seen in the cemeteries, with more robust bones, such as long bones and the os coxae, being used in the earlier cemeteries where the human remains had been exposed to the environment for a long period of time.

Table 5.2 Skeletal elements sampled for bone by cemetery.

Cemetery	Total number of bone samples	No. Cranium	No. Mandible	No. Vertebra	No. Rib	No. Humerus	No. Ulna	No. Radius	No. Os coxae	No. Femur	No. Tibia	No. Fibula	No. Patella
1001	**6**	2	1						1	1		1	
1002	**10**	1						1	1	5		1	1
1004	**14**	1		2	1	3	1			2	3	1	
734	**18**	8	2						2	5	1		
398	**18**	1											
755	**19**	1								1			
1003	**26**	2											

For the faunal samples 39 bone, five teeth and four wool samples were taken from 42 animals, with six animals yielding two tissue types. Thirty-five camelids were sampled, three birds (*Sula variegata*, Sulidae family and one unidentified species) and one each of fish, dog, cotton rat (*Sigmodon* sp.) and fox (*Lycalopex* sp.). Identification of the camelid remains to genus or species level was not attempted due to the morphological similarities of the four camelid species and the incomplete nature of the skeletal assemblage for each specimen (Shimada and Shimada 1985). The number of samples taken from each cemetery varied quite widely, although all suitable samples were taken (Table 5.3).

Table 5.3 Breakdown of faunal species sampled in each cemetery.

Cemetery	No. of camelids	Other species sampled
1001	3	1 fish
1002	3	
1004	8	3 birds, 1 cotton rat
734	2	
398	1	1 fox
755	7	
1003	11	1 dog

5.4 Comparative Plant Material

Archaeological plant remains were selected from previously sorted and identified material curated in the Museo Regional de Ica excavated in 2007 by Dr Beresford-Jones. The specimens selected were domesticated species and known edible wild plants (Table 5.4). Multiple samples of the same species, e.g. *Zea mays*, from different contexts were also selected in order to investigate inter-species variation. The samples were taken from Late Ocucaje, Late Nasca and Middle Horizon contexts.

Table 5.4 Archaeological plant material sampled from Late Ocucaje (EH) Late Nasca (EIP) and Middle Horizon (MH) contexts.

Species	Common name (Spanish/ English)	Part sampled	Time Period
Cyperaceae	Not identifiable	Stem	EIP
Gynerium sagittatum	*Caña brava*	Cane	EIP
Poaceae	Not identifiable	Stem	EIP
Phaseolus lunatus	*Pallar*, lima bean	Bean	EIP
Phragmites sp.	*Carrizo*	Cane	EIP
Gossypium sp.	Cotton	Seed	EIP
Zea mays	Maize	Cob	EIP
Canna edulis	*Achira*	Flower	EIP
Phaseolus vulgaris	*Fréjol*, common bean	Seed and pod	EIP
Lagenaria siceranea	*Mate*	Fruit	EIP
Prosopis sp.	*Huarango*	Pod	EIP
Inga sp.	*Pacay*	Leaf	EIP
Cucurbita sp.	*Zapallo*	Seed	EIP
Capsicum sp.	Chilli	Seed	EIP
Cenchrus sp.	*Pega pega*	Flower	EIP
Cucurbita sp.	*Zapallo*	Seed	EIP
Zea mays	Maize	Cob	EIP
Poaceae	Not identifiable	Flower	EIP
Arachis hypogaea	Peanut	Shell	EIP
Crotalaria sp.	Not identifiable	Seed	EIP
Psidium guajava	Guayaba	Seed	EIP
Salix sp.	Not identifiable	Leaf	EIP
Cyperaceae	Not identifiable	Stem	EIP
Manihot sp.	Manioc	Tuber	EH
Inga sp.	*Pacay*	Pod	EH
Amaranthaceae	Not identifiable	Seed	MH
Portulaca oleracea	Common purslane	Seed	MH
Amaranthaceae	Not identifiable	Seed	MH

These (n=28) were collected for carbon isotope analysis only, as a small sample is needed for carbon compared to a larger sample need for nitrogen. Analysis of the carbon isotopic values of these plants allows a comparison between modern and archaeological plant data, which should have a small difference due to the modern atmospheric $\delta^{13}C$ value having been altered through the burning of fossil fuels (Marino and McElroy 1991). The majority of the isotopic work to characterise the signal of the plant ecology in Peru has been carried out on modern plant specimens (Cadwallader *et al.* 2012; DeNiro and Hastorf 1985; Tieszen and Chapman 1992) and therefore it is essential to know how this relates to the background signal in the past.

5.5 Collagen Extraction from Human and Animal Remains

Methods used to extract collagen from the human and animal remains followed the standard operating procedures used in the Dorothy Garrod Laboratory for Isotopic Analysis, Division of Archaeology, University of Cambridge.

5.5.1 Bone Collagen

Collagen from bone samples was extracted using a method based on Richards and Hedges (1999) and Longin (1971). Briefly this involves sandblasting the bone (approximately 0.5g) to remove visible contaminants before leaving the sample in c.10ml 0.5M HCl (changed for fresh acid every 48 hours) at 4°C until the bone had demineralised. This took between one and three weeks. The sample was then rinsed three times in distilled water and pH3 water added. Samples were put in the oven for 48 hours at 75°C. The supernatant liquid containing the collagen was then Ezee filtered (using 8μm filters) into a clean plastic test tube. This was frozen at -80°C before being lyophilised. Weights were recorded throughout in order to quantify yields. Between 0.7mg and 0.9mg of the collagen was weighed into tin capsules in triplicate for analysis in the mass spectrometer.

5.5.2 Skin Collagen

Collagen from skin was extracted in a similar method to that of bone collagen. Initially skin samples (approximately 0.2g) were repeatedly rinsed in 2:1 methanol:chloroform (v/v) for 60 minutes at a time in an ultrasonic bath to remove lipids. This process also removed contaminating sediments and was repeated three or four times until the solvent was clear. Samples were then ultrasonicated in distilled water for 30 minutes three times. After this stage, the procedure followed that of bone collagen extraction – demineralisation in 0.5M

HCl for 48 hours, gelatinisation in pH3 water for 48 hours at 75°C, filtering, freezing and lyophilisation. Between 0.7mg and 0.9mg of the collagen was weighed into tin capsules in triplicate for analysis in the mass spectrometer.

5.5.3 Dentine

In order to attain sufficient amounts of collagen the roots of the teeth were used. One or two roots were cut from the tooth, well below the cervix of the crown, using a Dremel drill. The roots were sandblasted to remove any adhering contaminates. Samples were then treated in the same manner as the bone samples, with demineralisation taking between one and seven days. Gelatinisation and lyophilisation then followed. As with bone and skin collagen, between 0.7mg and 0.9mg of the collagen was weighed into tin capsules in triplicate for analysis in the mass spectrometer.

5.6 Keratin Preparation of Hair and Animal Wool

Human hair and animal wool samples were prepared using the method by O'Connell and Hedges (1999b). Briefly, the human samples were rinsed in 2:1 methanol:chloroform (v/v) for 30 minutes in a ultrasonic bath in order to remove any contaminants – lipids, adherent materials (e.g. nit eggs) etc. This was repeated multiple times – between 3 and 6 – until the solvent was clear. Samples were then rinsed in distilled water for a minimum of 3 and maximum of 7 times for 30 minutes in the ultrasonic bath before being air dried. At this point the samples approximate to pure keratin. Additionally, aluminium foil strips were also treated in this manner.

For samples longer than six centimetres approximately 20 strands were separated out from the main sample, carefully removing the proximal end from the tape securing it. Distilled water was used as necessary to keep the sub-sample as one coherent group. The sample was wrapped in the aluminium foil. The foil was then cut from the proximal end into one centimetre sections. Each of these was placed in an Eppendorf tube and lyophilised to remove any water. The dried sections were finally placed into large tin capsules and rolled into small balls ready for the mass spectrometer. The weight of each section is estimated to be approximately 0.8mg based on trials conducted in the laboratory.

For samples less than 6cm in length, bulk samples were taken. This involved selecting enough hairs to weigh approximately 0.8mg (based on trials this was twenty 1cm hairs or five

4cm hair for example) and wrapping them in small pieces of aluminium foil. This was done in triplicate. Samples were then lyophilised and placed in large tin capsules as with segmented samples.

Animal wool was treated in a similar fashion with two 30 minutes rinses in the ultrasonic bath in 2:1 methanol:chloroform followed by two rinses for 30 minutes in the ultrasonic bath in 2:1 chloroform:methanol. Samples were then rinsed twice in distilled water for 30 minutes in the ultrasonic bath. This extra step was to ensure complete removal of all lipids and contaminants in the thicker animal hair. Samples were then air dried.

Between 0.7mg and 0.9mg of hair from each sample was weighed into cleaned aluminium foil and rolled into small balls for the mass spectrometer. This was carried out in triplicate.

5.7 Preparation of Plant Material

Plant material was powdered using a ball mill and between 0.7mg and 0.9mg of powder was weighed into tin capsules in duplicate for the mass spectrometer.

5.8 Analytical Methods

All samples were analysed using a Costech elemental analyser coupled in continuous flow mode to a Finnigan mass spectrometer in the Godwin laboratory, Department of Earth Sciences, Cambridge. Carbon and nitrogen isotopic ratios were measured in comparison to international standards, VPDB and AIR using the delta scale. Repeated measurements on international and internal standards show the analytical error to be less than ±0.2‰ for both carbon and nitrogen for all tissues. This varied slightly between tissues as is shown in Table 5.5.

Table 5.5 Analytical errors for carbon and nitrogen isotopes for each tissue type analysed.

Tissue	Error on carbon (1σ)	Error on nitrogen (1σ)
Bone	0.07‰	0.15‰
Teeth	0.18‰	0.13‰
Skin	0.08‰	0.11‰
Hair	0.09‰	0.14‰

5.9 Summary of Materials and Methods Used in this Research

Crania were the preferred skeletal element targeted for sampling, although this was not possible in all cases, as the preservation of the remains varied among the cemeteries. Estimation of age and assessment of sex was carried out where possible on the human remains and any pathological changes to the skeletal elements present were recorded. Up to four different tissue types - bone, tooth, skin and hair - were sampled from each individual. All well preserved faunal samples were sampled regardless of element present as these were fewer in number than the human remains. Comparative plant material from archaeological contexts were also sampled in order to help define the carbon isotopic ranges of the plants in the past. Collagen was extracted and analysed from bone, tooth and skin samples, whereas hair can be considered pure keratin after a brief pre-treatment. The analytical errors associated with the mass spectrometry of the samples are well within acceptable limits for this type of research.

Chapter 6 Results

This chapter sets out the results from field observations of the human remains and isotopic analysis of human and faunal tissues from the Samaca and Ullujaya basins. The osteological results and pathological observations will be presented first, the details of which will be incorporated into the analysis and interpretation of the isotopic results in Chapter 8. The isotopic results of the human remains follow, describing an overview of the data for each tissue type and by the four time periods covered in this research. A similar treatment is given to the faunal remains and finally the isotopic results of the archaeological plant remains are presented. For full details of the osteological, pathological and isotope results see Appendices 2 to 5.

6.1 Osteological and Pathological Results

These data give context to the looted human remains studied in this research. At the individual level it will help in the identification of any association between disease or poor health and diet, and at the population level it will facilitate the analysis of the diet in terms of age and sex divisions within the population.

6.1.1 Demography

Whilst it is not possible to investigate the demography of each period due to the small sample size it is worth noting the overall distribution of sex and age of the samples taken. The sample was randomly selected within the cemeteries or sectors and was only influenced by the state of preservation. 68% of the total sample is made up of adult remains; of these adults, 45% were male or probable male and 34% female or probable female, with the remainder unsexed due to lack of features or ambiguity of features. Separated into each cultural period, the Middle Horizon and Late Intermediate Period reflect the overall sample in terms of male/female percentage (see Table 6.1). However the two early cultural phases have much higher percentages of individuals of unknown sex - 41% for the Early Horizon and 43% for the Early Intermediate Period. This is clearly due to the types of elements sampled (Table 5.2).

Table 6.1 Sex distribution of individuals sampled from each cemetery and time period. Juveniles were not sexed. Cemeteries 1001, 1002 and 1004 make up the Early Horizon sample, and cemeteries 398 and 755 comprise the Middle Horizon sample. The two other time periods are represented by one cemetery only.

Cemetery	n	Juvenile	Male	Probable male	Female	Probable female	Unknown adult	Unknown sex and age
1001	8	2	1	-	2	-	1	2
1002	11	5	-	1	1	2	2	-
1004	14	2	1	1	3	1	6	-
Early Horizon total	**33**	**9 (27%)**	**2 (6%)**	**2 (6%)**	**6 (18%)**	**3 (9%)**	**9 (27%)**	**2 (6%)**
734/ Early Intermediate Period total	**19**	**5 (26%)**	**2 (11%)**	**4 (21%)**	**1 (5%)**	**1 (5%)**	**6 (32%)**	**-**
398	19	3	6	3	4	1	1	1
755	21	7	5	3	-	3	1	2
Middle Horizon total	**40**	**10 (26%)**	**11 (28%)**	**6 (15%)**	**4 (10%)**	**4 (10%)**	**2 (5%)**	**3 (8%)**
1003/Late Intermediate Period total	**28**	**7 (25%)**	**7 (25%)**	**3 (11%)**	**2 (7%)**	**6 (21%)**	**2 (7%)**	**1 (4%)**
Overall total	**120**	**31 (26%)**	**22 (18%)**	**15 (13%)**	**13 (11%)**	**14 (12%)**	**19 (16%)**	**6 (5%)**

The majority of adult remains sampled fell into the Young Middle Adult and Old Middle Adult categories. This is more or less the case in each of the cultural periods, although the amount of unaged remains varies (see Table 6.2). As with the inability to sex some remains this is a reflection on the elements sampled as opposed to the preservation of the remains. The effect of deliberate cranial modification has been shown to affect the rate of suture closure, making Meindl and Lovejoy's (1985) aging method unreliable (O'Brien and Sensor 2008). However, in combination with other aging techniques, such as dental wear, age can still be estimated for these individuals. With these caveats acknowledged, the aim of aging the remains in this study, therefore, is to provide not absolute ages but relative ages in order to ensure individuals have been sampled across the age ranges.

Table 6.2 Number of individuals belonging to each age range in the four time periods.

Age Group	Age Range	Early Horizon n=33	Early Intermediate Period n=19	Middle Horizon n=40	Late Intermediate Period n=28
Foetus	<40 weeks	1	-	-	-
Early Childhood	1-6 years	7	1	4	1
Late Childhood	7-12 years	-	4	4	4
Adolescent	13-17 years	-	-	2	1
Juvenile unknown age	<18 years	1	-	-	1
Young Adult	18-25 years	4	1	4	3
Young Middle Adult	26-35 years	1	2	7	8
Old Middle Adult	36-45 years	5	4	10	5
Mature Adult	46-59 years	3	-	4	2
Old Adult	60+ years	-	-	-	-
Adult unknown age	18+ years	9	7	2	2
No age information		2		3	1

Just over a quarter (26%) of the individuals sampled were juveniles (n=31). Most juveniles, 52%, fell into the Early Childhood category (1-6 years), followed by Late Childhood (29%). In the Late Intermediate Period, individuals falling into the Late Childhood category were more numerous than any other. As the cemeteries have not been completely sampled and the anthropological recovery is incomplete, it is not possible to carry out a demographic reconstruction for these populations (Alesan *et al.* 1999). High mortality rates in children less than 5 years old have been observed in palaeodemographic reconstructions for Nasca and Wari children (Cagigao 2009; Drusini *et al.* 2001), which is broadly mirrored by the individuals sampled here.

For 4% (n=5) of the total sample no age or sex determinations could be made whatsoever.

6.1.2 Distribution of Tissue Types

For each individual tissue type (bone, tooth, hair and skin) representation varies in terms both of sample size and sex ratios within each cultural period (Table 6.3). For the adults, broadly all the tissues have good male and female representation for each time period. The variability in tissue types represented is largely due to the variation of element sampled between the cemeteries.

Table 6.3 Distribution of tissue types by time period and sex.

Time Period	n	Juvenile	M or M?	F or F?	Adult Unknown	Unknown
	BONE					
Early Horizon	**30**	8	4	9	9	-
Early Intermediate Period	**18**	5	5	2	6	-
Middle Horizon	**37**	10	17	9	1	-
Late Intermediate Period	**26**	6	10	8	2	-
	TOOTH					
Early Horizon	**8**	1	3	3	1	-
Early Intermediate Period	**6**	2	3	1	-	-
Middle Horizon	**35**	10	16	9	-	-
Late Intermediate Period	**21**	6	10	5	-	-
	SKIN					
Early Horizon	**1**	-	1	-	-	-
Early Intermediate Period	**0**	-	-	-	-	-
Middle Horizon	**8**	2	3	3	-	-
Late Intermediate Period	**10**	2	2	4	2	-
	HAIR					
Early Horizon	**8**	1	2	2	1	2
Early Intermediate Period	**4**	3	-	-	1	-
Middle Horizon	**28**	6	11	8	-	3
Late Intermediate Period	**20**	5	6	6	2	1

6.1.3 Pathological Observations

With the exception of nit eggs (*Pediculus humanus capitis*) present in four hair samples all the pathologies discussed below were observed on the bone. Skeletal pathologies are useful for inferring information such as health of a community, environmental stresses, diet, illnesses and social relations (e.g. instances of inter-personal violence or provision of health care). Briefly, the pathologies observed in the sample populations are given below and the most probable aetiologies for these. A summary of all the individuals with observed pathologies is given at the end of this section in Table 6.5.

Dental

Dental pathologies were the most commonly observed due to the sampling strategy employed. Common pathologies observed were carious lesions, abscesses and ante-mortem tooth loss (for example see Figure 6.1). These were ubiquitous throughout the cemeteries. Some individuals had lost a substantial number of teeth (up to 15). Ante-mortem tooth loss

was commonly associated with the presence of abscesses. The poor dental health observed in many individuals is likely to be indicative of the diet consumed. High sugar content, from starches or sugars, is known to be a cause of caries (Hillson 2002). The carious lesion can then develop into an infection of the pulp, i.e. an abscess, which ultimately can lead to ante-mortem tooth loss (Aufderheide and Rodríguez-Martín 1998:403).

Only one incident of linear enamel hypoplasias was observed macroscopically and its general absence from the sampled populations indicates that stressful events during childhood that would affect growth were not common (Aufderheide and Rodríguez-Martín 1998:405; Hillson 2002).

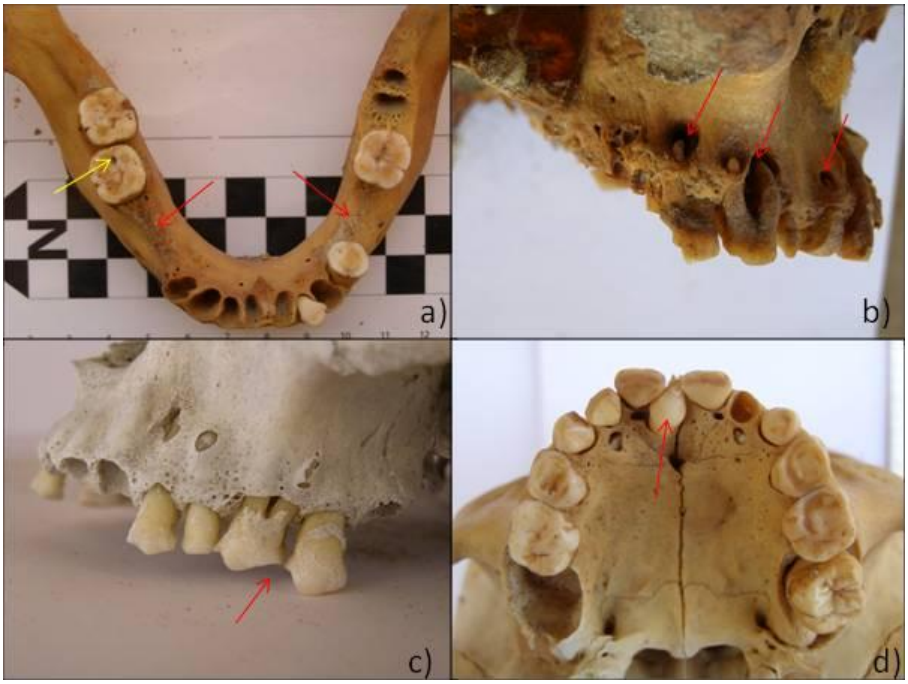

Figure 6.1 Examples of dental pathologies: a) Individual 16 (Cemetery 734) ante-mortem tooth loss (red arrows) and a carious lesion (yellow arrow); b) Individual 24 (Cemetery 398) abscesses (arrowed); c) Individual 26 (Cemetery 398) unusual pattern of tooth wear; d) Individual 48 (Cemetery 755) supernumerary tooth (arrowed). Photographs by author.

Pathologies of no clinical significance were also observed in a small number of individuals, including an impacted 3rd molar, supernumerary teeth, crowding and two possible cases of minor ante-mortem cusp breakage. Finally, unusual patterns of wear were observed for two

individuals. Individual 31 (Cemetery 1003) showed a clear preference for using the right-hand side teeth, whereas Individual 26 (Cemetery 398) exhibited increased wear on the left upper 1st and 2nd molars where the teeth meet on the occlusal surface (see Figure 6.1). As neither individual exhibits pathologies on the unworn side that would suggest it was painful to use this side, the uneven wear most likely to be due to repeated activity involving these teeth.

Dental pathologies are much more numerous than any other type of pathology and prevalent in all time periods. The prevalence of dental pathologies can be worked out by using the number of observable teeth or socket as the maximum number. For example, the prevalence of carious lesions for each individual is worked out by:

number of carious lesions observed/total number of teeth observed*100.

Far more individuals in the later two time periods had dentition available for study and thus will affect the calculated prevalence somewhat. Carious lesions, abscesses and ante-mortem tooth loss were the most common types of pathologies. For each individual the percentage that they score for the three pathologies can be rated according to its severity using the scale:

% of teeth affected	Score
0	0
1-33	1
34-66	2
67+	3

Combining the three scores, achieves a total score, shown in Table 6.4 for each cemetery.

Table 6.4 Number of individuals in each total score range per cemetery. The higher the total score the worse the overall dental pathologies the individual had.

	Cemetery						
Total Score	**1001**	**1002**	**1004**	**734**	**398**	**755**	**1003**
0	1	1	0	3	4	6	9
1-3	2	1	2	4	10	12	10
4-6	1	0	0	0	4	0	4
7+	0	0	0	0	0	0	0

From this the distribution of dental pathologies is broadly similar in all of the cemeteries. However, this method does not account for the fact that if many teeth have been lost ante-mortem then the individual will have low scores for carious lesions and abscesses. For eight individuals over a third of observable teeth sockets show ante-mortem tooth loss. These come from three cemeteries - 1001 (n=1), 398 (n=3) and 1003 (n=4).

It is difficult to drawn any substantial conclusion about what the dental data mean in terms of diet. A higher rate of caries and tooth loss would suggest a higher level of sugar in the diet. Maize and *huaranga* are both sugary foods, which have been identified in the lower Ica Valley archaeobotanical record (Beresford-Jones *et al.* 2011b), thus making it problematic to attribute the dental pathologies to consumption of a particular food.

Trauma

Only a few incidences of traumatic injuries were observed. In Cemetery 1004, Individual 6 had a healed rib fracture. A callous of compact bone was present (30x18mm), indicating that the fracture had healed considerably, as this stage is thought to take 1-2 years to reach (Dandy 1993). This type of injury can have many causes including accidental, e.g. falling, and interpersonal violence.

Three individuals exhibited small ectocranial depressions. One individual (38 from the Late Intermediate Period sample) had three healed depressions that were smooth edged and shallow, measuring 13x8mm (maximum) and all oval or circular in shape. The other two individuals (50 and 43 from the Middle Horizon and Late Intermediate Period samples respectively) had lesions that were in the process of healing. The depressions were shallow, not penetrating the diploic space, with slightly sharp edges. These lesions are very similar to those reported by Zimmerman *et al.* (1981), who attributed them to slingshot traumas.

Infections

Only chronic infections will be manifested in skeletal changes due to the length of time taken for the bone to respond to the infection (Ortner and Putschar 1981:105). The infectious pathologies observed in this research therefore would have had a long term effect on the individual, although not necessarily of any significance. Without the complete skeleton it is difficult to diagnose the infectious pathologies as diagnosis is often aided by the ability to identify patterns across the skeleton, e.g. for tuberculosis, treponemal diseases (Roberts 2009:159). Indeed, even with the complete skeleton many morphological patterns overlap further complicating diagnosis (Ortner and Putschar 1981:105; Roberts 2009:159). One

individual (12 from the Early Intermediate Period sample) exhibited diffuse new woven bone across the entire diaphyses of both femora. The new bone was striated and porous and the linea aspera was heavily speculated. The articular surfaces were not affected (Figure 6.2). The new bone formation on the femora can only be diagnosed as a response to a non-specific infection due to the absence of pathologies observed on other skeletal elements.

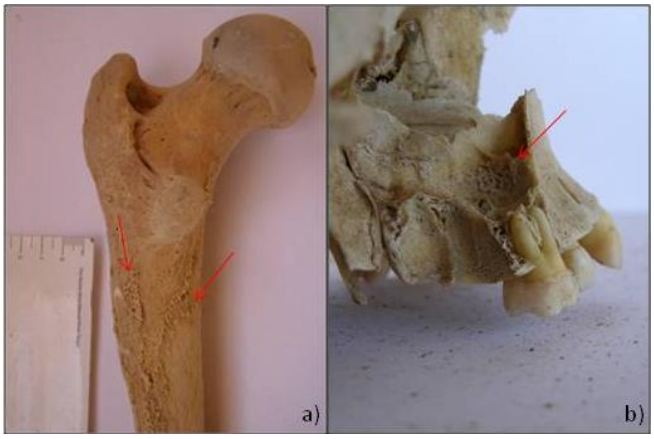

Figure 6.2 Examples of infectious pathologies observed: a) Periostitis seen on the posterior surface of the left femur of Individual 12 (Cemetery 734); b) New bone formation indicative of maxillary sinusitis, Individual 51 (Cemetery 755). Photographs by author.

Two individuals (one from the Early Intermediate Period sample and the other from the Middle Horizon sample) were identified as suffering from maxillary sinusitis, evident by the new bone formation in the sinus (Figure 6.2). This bone forms in response to a non-specific inflammation, which would have been chronic as the bone forms over a long time (Lewis *et al.* 1995).

Individual 50 (Cemetery 755) had small areas of new bone formation around the mastoid processes and occipital region of the skull. These were fragmentary, most likely to having been damaged taphonomically. Given that healing ectocranial lesions were also observed for this individual (see above), it is probable that this new bone formation is secondary to the trauma when inflammation of the surrounding tissues was caused. It is possible that this inflammation is due to a separate incident but in this case the cause would be unknown.

Joint and Activity

Individual 119 (Cemetery 1003) was observed to have a shallow left temporomandibular socket, with a smooth, depressed area with bony rim placed anteriorly (Figure 6.3a). This is a new articular facet for what would have been a dislocated temporomandibular joint on the left side only (Aufderheide and Rodríguez-Martín 1998:400). This may be related to a traumatic event but there is no evidence for this (the mandible was missing).

Figure 6.3 Examples of pathologies involving joints: a) New temporomandibular articular surface (arrowed) observed for Individual 119 (Cemetery 1003) located next to the normal joint surface (circled in white); b) Kyphosis of the spine, Individual 68 (Cemetery 1004); c) Vertebral osteoarthritis seen in Individual 47 (Cemetery 1003); d) Two fused vertebrae seen in Individual 57 (Cemetery 1001). Photographs by author.

Individual 57 (Cemetery 1001), a mature adult male, has several fused vertebral (lumbar) bodies. L4 and L5 are clearly fused on the anterior left side with smooth, compact bone in a rounded arch between the bodies (Figure 6.3d). Three other vertebrae (tentatively identified as L1-3) show the same type of fusion. In all cases the right side of the vertebral body, the neural arches and the articular facets are not affected. Prominent and excessive enthesophytes

are present across the whole right os coxae and fragment of the left side that is present. Areas that are especially affected are the pubic tubercle, ischium and iliac crest. Due to the incompleteness of this individual it is difficult to accurately diagnose this pathology. One possibility is DISH (diffuse idiopathic skeletal hyperostosis), a condition of unknown aetiology but often associated with diabetes (Aufderheide and Rodríguez-Martín 1998). However, in this condition the right side of the vertebral bodies fuse rather than the left, due to the presence of a major blood aorta on the left. Another possibility is degenerative joint disease or spondylosis of the vertebra, caused by either herniation of the intervertebral disk or loss of disk space and irritation and stimulation on the periosteum. Both result in formation of new bone, which if it is chronic, can cause complete fusion of the vertebral bodies, especially in the lumbar region (Aufderheide and Rodríguez-Martín 1998; Ortner and Putschar 1981). The changes seen on the os coxae could also be due to degenerative joint disease, especially seen around the sacroiliac joint (Aufderheide and Rodríguez-Martín 1998). Activity may also be responsible for these as well.

Individual 68 (Cemetery 1004) has an anterior curvature of the spine (Figure 6.3b). There is no loss of the structure of the vertebral bodies. This kyphosis is often associated with old age yet the age of this individual has been estimated at 36-45 years. Another aetiology may be congenital.

Four individuals have been identified as having osteoarthritis due to the presence of osteophytes and eburnation of the effected joint. Vertebral osteoarthritis was observed in Individuals 70 (lumbar) and 47 (cervical), from the Early Horizon and Late Intermediate Period samples respectively (Figure 6.3c). Osteoarthritis of the temporomandibular joint was observed for Individuals 46 and 119, both from the Late Intermediate Period sample. In the latter case it is likely that this is secondary osteoarthritis to the dislocation. Osteoarthritis, one of the most common pathologies observed has many aetiologies, including activity, age and genetic predisposition (Weiss and Jurmain 2007).

Small bony projections at the margin of a joint, osteophytes, are seen in four individuals from Cemetery 1004 (60, 67, 70 and 72). These all occur on the vertebral column and are indicative of repeated stress on the joint. Small bony projections at the site of muscle attachments, enthesopathies, are evident in two individuals (118 and 52). For Individual 118 (from the Early Horizon sample) muscle attachments on the clavicle, femur and humerus are

pronounced. For Individual 52 (from the Middle Horizon sample) the muscle attachments along the nuchal line at the posterior of the skull are pronounced.

Metabolic

Six individuals from the Middle Horizon and Late Intermediate Period cemeteries have been noted as having porosity or penetrative lesions into the diploic space of the roofs of the orbits. These are usually small and located anteriorly (Figure 6.4). Five of these individuals are children aged between 5 and 8 years. There is also a case of an adult male where smaller lesions in the same location have been observed but with rounded margins indicating healing of the condition. This pathology is commonly identified as cribra orbitalia (Aufderheide and Rodríguez-Martín 1998:350; Ortner and Putschar 1981:258), a condition linked with iron-deficiency anaemia. However, recent research has shown that the changes induced by iron-deficiency anaemia do not produce the marrow hypertrophy, i.e. porosity, observed in the roof of the orbits (Walker *et al.* 2009). The causes of the skeletal changes seen are most likely due to a combination of factors, with deficiency in vitamin B_{12} a key factor (Walker *et al.* 2009). These are considered to be indicative of a significantly stressful period during life (Aufderheide and Rodríguez-Martín 1998:405).

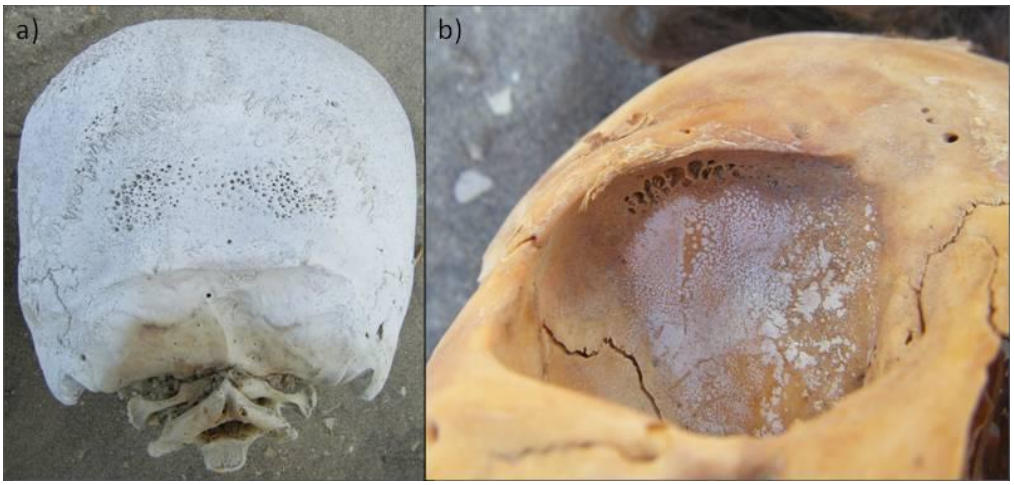

Figure 6.4 Examples of metabolic pathologies observed during this research: a) Porotic hyperostosis, Individual 106 (Cemetery 734); b) Bony changes associated with cribra orbitalia, Individual 100 (Cemetery398). Photographs by author.

Porosity that penetrates to the diploic space on the occipital bone has been observed for one adult individual (Individual 106 from Cemetery 734, see Figure 6.4). Despite taphonomic damage due to exposure to the sun, the pathology is evident. Like cribra orbitalia this is hypertrophy of the marrow (diploe) and has been diagnosed as porotic hyperostosis (Aufderheide and Rodríguez-Martín 1998:349; Ortner and Putschar 1981:258). The cause has again been frequently linked to iron-deficiency anaemia but Walker *et al.* (2009) argue that whilst dietary-deficiencies are clearly linked to this condition (and cribra orbitalia) it is a combination of poor nutrition, poor sanitation, infectious diseases and cultural practices that is responsible for the high levels generally seen in the archaeological record.

Congenital

Congenital pathologies have a wide variety aetiologies, including genetic, metabolic, environmental and traumatic factors (Barnes 2008). All of the congenital pathologies observed in the sampled population are unlikely to have been of any clinical significance. These include sacralisation of 5^{th} lumbar vertebra, small extra bony projections, a retained metopic suture, plagiocephaly and asymmetry of cranial features, e.g. orbits, mastoid processes and occipital condyles. In the case of the last conditions the aetiology may be activity-related, involving a movement that turned the head more frequently to one side more than the other.

Neoplasm

Only benign neoplasms were identified in the sample population. These are not of clinical significance and are unlikely to have been evident to the living populations. One case of a fibrous cortical defect was observed (Figure 6.5). These are common in modern populations and usually occur at the metaphyses as seen in this example (Aufderheide and Rodríguez-Martín 1998). A differential diagnosis would be activity-related trauma as this is the site of the medial head of gastrocnemius attachment. Two individuals are recorded as having small, round bony protuberances on their skulls (Figure 6.5), which have been diagnosed as button osteomas (Aufderheide and Rodríguez-Martín 1998) – slow growing, localised and non-invasive neoplasms (Mann and Murphy 1990).

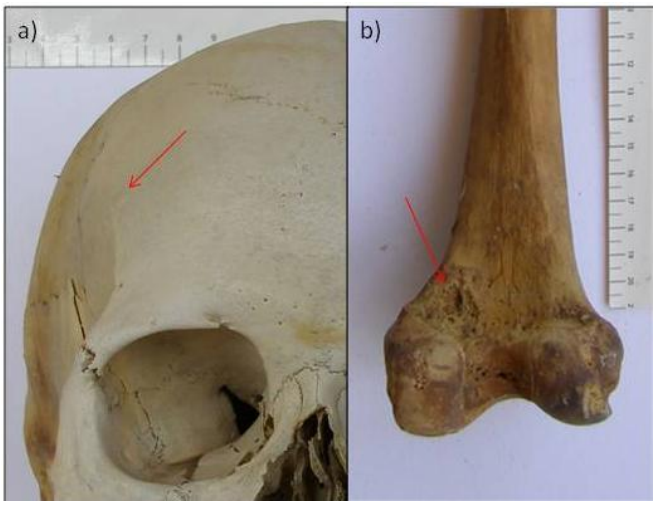

Figure 6.5 Examples of neoplasms: a) Button osteoma seen on the skull of Individual 38 (Cemetery 1003); b) Cortical defect seen on the posterior femur of Individual 15 (Cemetery 734). Photographs by author.

Cranial deformation

Two types of cranial deformation have been observed in the sampled populations. From Early Horizon Cemetery 1001, two individuals have circumferential deformation. Following the definition given by Pomeroy *et al.* (2010) this is narrowing and posterio-superior elongation of the cranial vault. This is typical of the type of deformation in Paracas populations.

Four individuals have been observed with 'bilobed' deformation - flattening of the occipital with frontal modification and depression of the sagittal suture resulting in a two distinct lobes formed in the parietal region (Pomeroy *et al.* 2010). Three of these individuals come from the Early Intermediate Period cemetery (Individuals 105, 106 and 110) and the other is from Middle Horizon cemetery 755 (Individual 19). Nasca cranial deformation was common but not universal (Browne *et al.* 1993) and two types have been observed (Silverman and Proulx 2002). The practice was used to identify a person to a particular social grouping but as it was not a universal practice and no detailed study has been carried out investigating trends between cranial deformation and social status it is difficult to attach any meaning to the observations made here.

Table 6.5 Summary of the individuals with pathologies observed. An X in the dental column indicated the presence of dental pathologies. These were deemed to be too numerous to include on this table.

Ind.	Cem.	Time Period	Dental	Trauma	Infectious	Joint/Activity	Metabolic	Congenital	Neoplasm	Cranial Deformation
55	1001	Early Horizon								Circumferential
57	1001	Early Horizon	X			Severe fusion of vertebrae				
112	1002	Early Horizon						L5 Sacralisation		
118	1002	Early Horizon	X			Upper limb enthesopathies				
6	1004	Early Horizon		Healed rib fracture						
60	1004	Early Horizon				Vertebral osteophytes				
67	1004	Early Horizon				Vertebral osteophytes				
68	1004	Early Horizon	X			Kyphosis				
70	1004	Early Horizon				Vertebral osteoarthritis				
72	1004	Early Horizon				Vertebral osteoarthritis				
12	734	Early Intermediate Period			Non-specific infection					
15	734	Early Intermediate Period							Benign cortical defect	

104	734	Early Intermediate Period			Maxillary sinusitis					
105	734	Early Intermediate Period	X							x
106	734	Early Intermediate Period					Porotic hyperostosis			Bilobal
109	734	Early Intermediate Period	X					Extra bone on skull		
110	734	Early Intermediate Period						Retained suture		Bilobal
91	389	Middle Horizon	X					Asymmetry on skull		
98	398	Middle Horizon	X					Asymmetry on skull		
100	398	Middle Horizon					Cribra orbitalia			
19	755	Middle Horizon	X							Bilobal
20	755	Middle Horizon					Cribra orbitalia			
22	755	Middle Horizon	X				Healed cribra orbitalia			
50	755	Middle Horizon	X	Cranial lesion	Periostitis on skull					
51	755	Middle Horizon	X		Maxillary sinusitis					

52	755	Middle Horizon	X			Cranial enthesopathies				
53	755	Middle Horizon	X					Asymmetry on skull		
83	755	Middle Horizon	X					Asymmetry on skull	Benign neoplasm	
84	755	Middle Horizon					Cribra orbitalia			
36	1003	Late Intermediate Period						Extra bone on skull		
38	1003	Late Intermediate Period	X	Cranial lesions					Benign neoplasm	
43	1003	Late Intermediate Period	X	Cranial lesion						
46	1003	Late Intermediate Period	X			Osteoarthritis in jaw				
47	1003	Late Intermediate Period	X			Vertebral osteoarthritis				
76	1003	Late Intermediate Period	X					Asymmetry on skull		
78	1003	Late Intermediate Period	X				Cribra orbitalia			
79	1003	Late Intermediate Period					Cribra orbitalia			

119	1003	Late Intermediate Period	X			Dislocation and arthritis in jaw				
121	1003	Late Intermediate Period					Cribra orbitalia			

It would be ill advised to discuss prevalence of certain pathologies in the individual cemeteries or time periods as the lack of complete skeletal data and the relatively small population sizes may mask or exaggerate prevalence. A few interesting observations can be noted, although they should be used with caution. The majority of the cases of vertebral joint pathologies (osteoarthritis, osteophytic activity etc) belong to the Early Horizon cemeteries. This may be partly due to the higher presence of vertebral elements in this sample set but it does indicate that the activities carried out by the people in this period involved repetitive strain on the back. There is a higher incidence of metabolic pathologies, namely, cribra orbitalia in the later two time periods. Although crania were sampled in most cases, the small number of samples in the earlier periods makes it difficult to assess fully whether the higher number in the later periods is a valid trend. Likewise the few incidences of cranial trauma observed fall into the later periods but the full importance of this is difficult to assess.

6.2 Isotopic Analysis

This section details the results of the isotopic analyses of both human and faunal samples. A comparison of basic results for the cultural periods is given in this section. More detailed description of the data (spread, averages etc) is given in Chapter 7, where the results are dealt with in more detail.

6.2.1 Human Samples

Bone

Extraction of collagen from bone samples was attempted for a total of 111 human samples. The isotopic results from the collagen were deemed to be successful when the yield was greater than 5%, the percentage carbon greater than 13% and nitrogen greater than 4%, and a C/N ratio within the range given by DeNiro (1985) of 2.9-3.6. Of the human samples run, four failed to produce a sufficient yield to be analysed and four failed on the C/N ratio.

For the successful 103 samples, which were not normally distributed (see Table 6.6), the $\delta^{13}C$ values ranged from -17.5‰ to -8.8‰ with a median of -13.6‰ and first and third quartiles of the inter-quartile range (IQR) are -15.6‰ and -10.9‰ respectively. The $\delta^{15}N$ values ranged from 6.8‰ to 12.9‰, with a median of 9.6‰ and first and third quartiles of 8.9‰ and 10.0‰ respectively.

The average $\delta^{13}C$ value for the time periods becomes more positive over time, with a difference of 6‰ between the median Early Horizon and Late Intermediate Period values (see Figure 6.6 and Table 6.10). The range of carbon values for each time period also differs, with the Early Horizon, Early Intermediate Period and Late Intermediate Period having tight clusters around the average. The Early Horizon mean is -16.0 ±1.2‰ and the median is -16.3‰ with an IQR of -16.9‰ to -15.7‰, the Early Intermediate Period has a mean of -14.8 ±0.8‰ and a median of -14.7‰ and IQR of -15.4‰ to -14.2‰, and the Late Intermediate Period has a mean of -10.6 ±1.3‰ median of -10.3‰ and IQR between -11.2‰ and -9.8‰ for the later period. The Middle Horizon conversely has a much wider spread of data with a mean of -13.1 ±1.9‰ and median of -13.3‰ with an IQR of -14.3‰ to -11.9‰.

The nitrogen values for all cemeteries are fairly similar. The mean values all fall within 1‰ of each other, ranging between 9.2‰ (Early Intermediate Period) and 9.8‰ (Early Horizon). The standard deviations vary slightly between the cemeteries, with the lowest (±0.8‰ for the Middle Horizon) being half that of the highest (±1.6‰ for the Early Horizon). The constancy of the nitrogen values over time reflects the constancy of the camelid data from the four time periods (see Section 6.2.2).

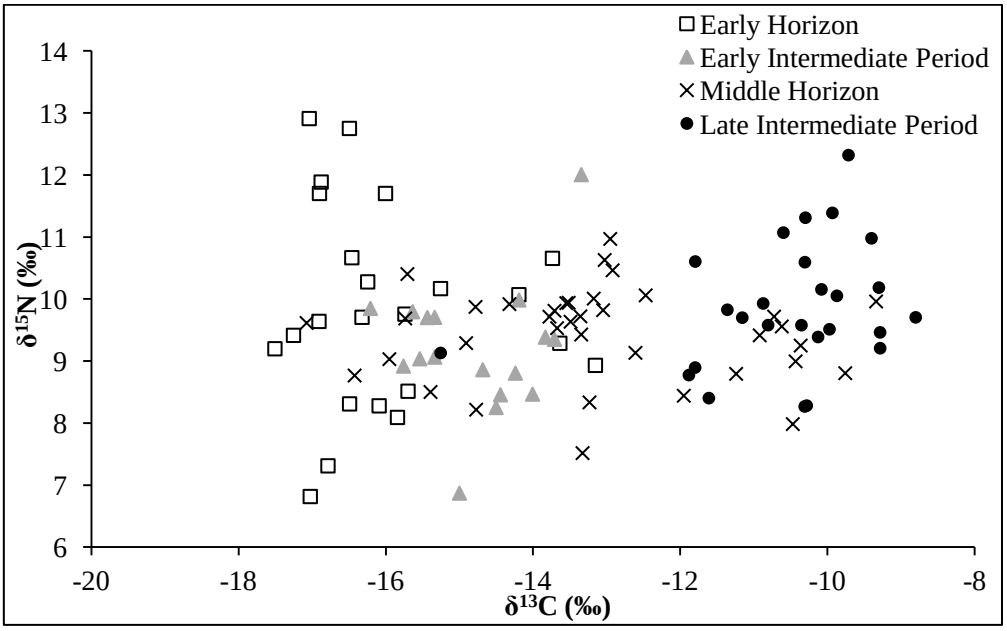

Figure 6.6 Human bone collagen data by time period for all the individuals with useable bone isotope results.

Tooth

In total 61 tooth samples were analysed. Seventy human teeth samples were brought back to the UK. Nine of the human teeth were discarded from analysis as they were from early forming teeth, and were not appropriate for the type of analysis to be conducted. As the collagen extracted from the dentine is the same type as bone, the criteria for assessing the quality of the collagen was the same as above. All samples, except one human tooth, met these criteria.

The carbon isotopic values for the 60 tooth samples with acceptable results are not normally distributed. All the values range from -16.8‰ to -9.2‰, with a median of -13.5‰. The first quartile is -15.1‰ and the third -10.9‰. The nitrogen data for all of the samples are normally distributed. It ranges from 7.4‰ to 11.8‰, with a mean of 9.7 ±0.9‰ (1σ). The median, first and third quartiles are 9.8‰, 9.1‰ and 10.4‰ respectively.

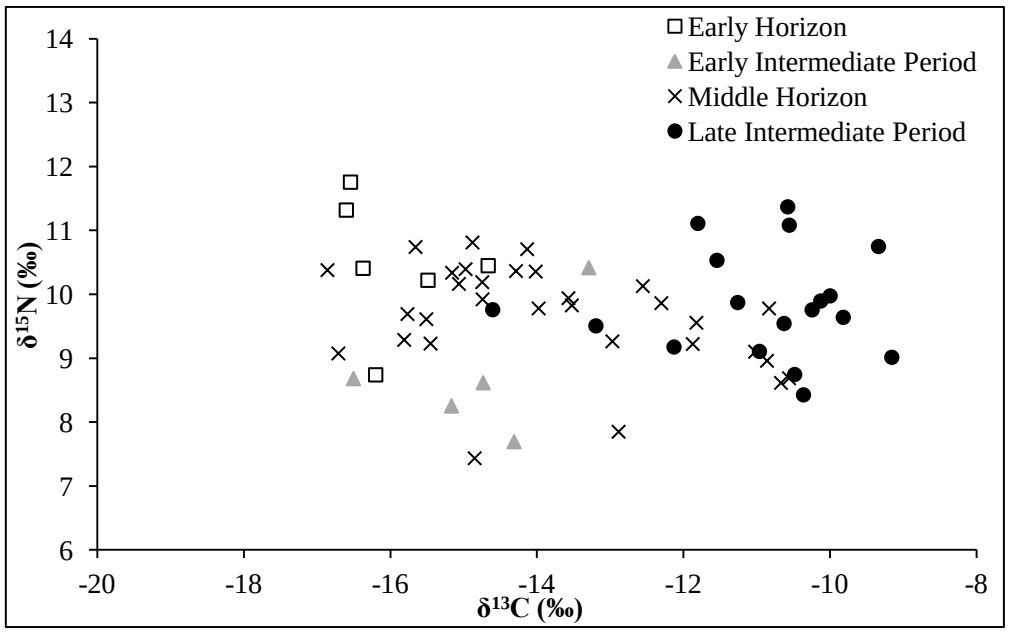

Figure 6.7 Human tooth collagen isotopic data by time period.

The tooth data by time period reflect the general trend seen in the bone data for carbon isotopic values (Figure 6.7). There is again an increase in mean over time from -16.0‰ for the Early Horizon to -10.9‰ for the Late Intermediate Period (Table 6.11). The standard

variations for each time period differ slightly from the bone data but the Middle Horizon remains the most spread (1σ = ±1.8‰) with the other more tightly clustered around the mean.

The nitrogen values in the tooth data by time period are more variable than the bone values, with the means ranging from 8.7‰ (Early Intermediate Period) to 10.5‰ (Early Horizon). The standard deviations of the data are very similar across the time periods, at ±1.0‰ for the two earlier time periods and ±0.8‰ for the two later time periods.

Skin

Nineteen samples of human skin collagen were analysed. Again, the collagen from the skin was judged on the same criteria as the bone and tooth samples. All of the samples were well preserved according to these criteria.

The skin data are normally distributed for both isotopes. The carbon data range from -15.3‰ to -7.8‰ for all samples, with a mean and one standard deviation of -11.8 ±2.1‰. The nitrogen data range from 10.8‰ to 14.9‰, with a mean and one standard deviation of 12.6 ±1.1‰.

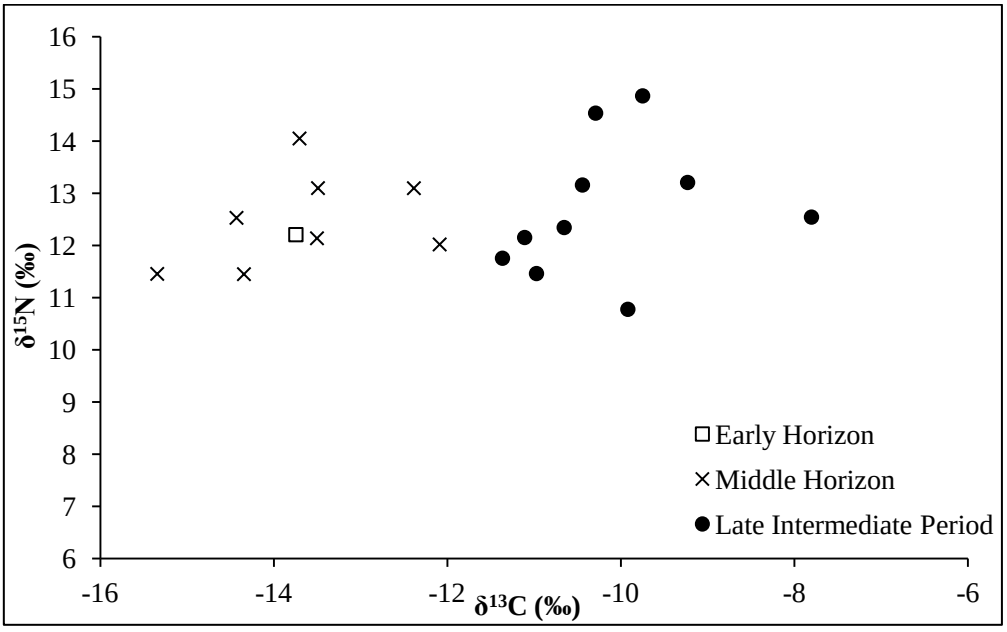

Figure 6.8 Human skin collagen isotopic data by time period.

It is more difficult to compare skin data across the time periods due to the distribution of the samples taken (Table 6.8). The Early Horizon is represented by only one sample and the

Early Intermediate Period by none. The Middle Horizon (n=8) and Late Intermediate Period (n=10) samples are similar in their mean carbon isotopic values to the bone and tooth data, with values of -13.7‰ and -10.2‰ respectively (Table 6.12). The standard deviations for both time periods are the same (±1.1‰). The nitrogen isotopic values are much higher than the other tissue types but are roughly equal, with similar spreads (12.5 ±0.9‰ and 12.7 ±1.3‰ respectively), mirroring what is observed in the bone data (Figure 6.8).

Hair

Sixty human hair samples were sampled in the field. Of these three were not run due to the brittle nature of the hair or the lack of sufficient material, 53 produced good results and four did not. Results were deemed successful when the C/N ratio was in the range of 3.0-3.8 (O'Connell and Hedges 1999a) and the amplitudes for both carbon and nitrogen fell within half to double the range of the amplitude for the standard alanine. From the 53 acceptable samples, 41 had been segmented and the remainder analysed in bulk.

For the 53 samples (taking either the bulk value or the mean of the segments for each individual), the data are normally distributed for both isotopes. For $\delta^{13}C$ the values range from -17.7‰ to -9.1‰, with a mean of -13.5 ±2.5‰. For $\delta^{15}N$ the range varies between 6.9‰ to 13.4‰, with a mean of 9.2 ±1.3‰.

Again, by time period the carbon values for the hair show a very similar trend to that in the bone data (Figure 6.9). All of the values are slightly more negative than the other tissues reflecting the difference between collagen and keratin, still the relationship between them is maintained. The means change from -17.1 ±0.7‰ for the Early Horizon, to -16.5 ±1.2‰ for the Early Intermediate Period, to -13.9 ±1.9‰ for the Middle Horizon and finally to -11.4 ±1.4‰ for the Late Intermediate Period (Table 6.13). The standard deviations are most similar to those seen for the tooth data, again showing the widest spread to be in the Middle Horizon.

The means of the nitrogen values are all within 1‰ of each other, similar to the bone values, ranging from the lowest of 9.0‰ (Middle Horizon) to 9.7‰ (Early Horizon). However, the standard deviations are on the whole greater than what was observed in the other tissues. The Early Intermediate Period has the widest spread of ±2.3‰, although the sample size is only four. The other three time periods have standard deviations ranging from ±1.0‰ (Early Horizon) to ±1.4‰ (Late Intermediate Period).

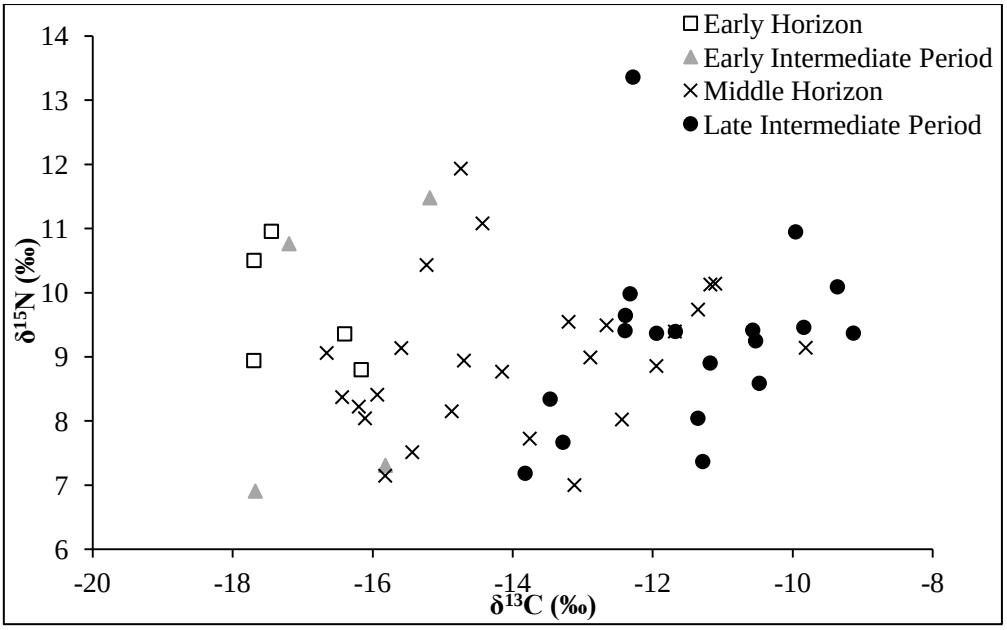

Figure 6.9 Human hair keratin isotope data by time period. For those individuals with segmented samples analysed, the mean value has been plotted here.

These results can be broken down by time period and by cemetery. The results are summarised in Tables 6.6 to 6.13. An asterisk (*) indicates which measure of average is more suitable based on whether the data were normally distributed (mean) or not normally distributed (median).

Table 6.6 Summary of the isotopic results from bone samples by cemetery. Cemeteries 1001, 1002 and 1004 date to the Early Horizon; Cemetery 734 to the Early Intermediate Period; Cemeteries 398 and 755 to the Middle Horizon; and Cemetery 1003 to the Late Intermediate Period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Cem.	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
1001	**6**	-16.9*	0.5	-17.5	-17.3	-17.0	-16.9	-16.0	11.1*	1.5	9.2	9.4	11.7	11.9	12.9
1002	**6**	-15.5	1.6	-17.0	-16.5	-16.3*	-13.7	-13.2	9.1*	1.4	6.8	8.3	9.3	10.3	10.7
1004	**11**	-15.7*	1.0	-16.9	-16.5	-15.8	-15.5	-13.6	9.5*	1.5	7.3	8.4	9.6	10.1	12.8
734	**17**	-14.8*	0.8	-16.2	-15.4	-14.7	-14.2	-13.3	9.2*	1.1	6.9	8.8	9.1	9.7	12.0
398	**18**	-13.6*	1.3	-15.7	-14.8	-13.4	-13.0	-10.6	9.5*	0.7	8.2	9.3	9.7	9.9	10.6
755	**19**	-12.7*	2.3	-17.1	-13.7	-13.0	-10.6	-9.3	9.3*	0.8	7.5	8.8	9.4	9.8	11.0
1003	**26**	-10.6	1.3	-15.3	-11.2	-10.3*	-9.8	-8.8	9.7*	1.0	8.3	9.2	9.7	10.6	12.3

Table 6.7 Summary of the tooth isotopic data by cemetery. Cemeteries 1001, 1002 and 1004 date to the Early Horizon; Cemetery 734 to the Early Intermediate Period; Cemeteries 398 and 755 to the Middle Horizon; and Cemetery 1003 to the Late Intermediate Period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Cem.	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
1001	**2**	-16.6	0.0	-16.6	-16.6	-16.6	-16.5	-16.5	11.5	0.1	11.3	11.3	11.5	11.8	11.8
1002	**1**	-14.7							10.5						
1004	**3**	-16.0*	0.5	-16.4	-16.3	-16.2	-15.8	-15.5	9.8*	0.9	8.7	9.5	10.2	10.3	10.4
734	**5**	-14.8*	1.2	-16.5	-15.2	-14.7	-14.3	-13.3	8.7*	1.0	7.7	8.3	8.6	8.7	10.4
398	**17**	-14.2	1.5	-15.8	-15.5	-14.9*	-13.6	-10.8	9.8*	0.8	7.4	9.6	9.9	10.3	10.8
755	**14**	-13.3*	2.1	-16.9	-14.7	-13.2	-11.0	-10.6	9.5*	0.8	7.9	9.0	9.4	10.2	10.7
1003	**18**	-10.9*	1.4	-14.6	-11.5	-10.6	-10.1	-9.2	9.8*	0.8	8.4	9.2	9.8	10.5	11.4

Table 6.8 Isotopic results summary for the skin samples analysed for each cemetery. Cemetery 1002 dates to the Early Horizon; Cemeteries 398 and 755 to the Middle Horizon; and Cemetery 1003 to the Late Intermediate Period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Cem.	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
1002	**1**	-13.7							12.2						
398	**4**	-13.9*	0.5	-14.4	-14.4	-13.9	-13.5	-13.5	12.3*	0.7	11.5	11.8	12.3	12.8	13.1
755	**4**	-13.4*	1.5	-15.3	-14.5	-13.0	-12.2	-12.1	12.7*	1.2	11.5	11.7	12.6	13.6	14.1
1003	**10**	-10.2*	1.1	-11.4	-11.0	-10.4	-9.8	-7.8	12.7*	1.3	10.8	11.8	12.4	13.2	14.9

Table 6.9 Summary of the isotopic results from the hair samples by cemetery. Cemeteries 1001 and 1004 date to the Early Horizon; Cemetery 734 to the Early Intermediate Period; Cemeteries 398 and 755 to the Middle Horizon; and Cemetery 1003 to the Late Intermediate Period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Cem.	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
1001	**2**	-17.6	0.2	-17.7	-17.7	-17.6	-17.4	-17.4	10.0	1.4	8.9	8.9	10.0	11.0	11.0
1004	**3**	-16.8	0.8	-17.7	-17.0	-16.4	-16.3	-16.2	9.6	0.9	8.8	9.1	9.4	9.9	10.5
734	**4**	-16.5*	1.2	-17.7	-17.4	-16.5	-15.5	-15.2	9.1*	2.3	6.9	7.1	9.0	11.1	11.5
398	**17**	-14.0*	1.7	-16.7	-15.2	-14.2	-12.7	-11.1	8.9*	1.2	7.0	8.2	8.9	9.4	11.9
755	**9**	-13.8*	2.5	-16.4	-15.8	-14.4	-11.4	-9.8	12.7*	1.2	7.2	8.4	9.1	9.7	11.1
1003	**19**	-11.4*	1.4	-13.8	-12.4	-11.4	-10.5	-9.1	9.3*	1.4	7.2	8.5	9.4	9.6	13.4

Table 6.10 Bone isotopic results summary by time period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Period	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
Early Horizon	**23**	-16.0	1.2	-17.5	-16.9	-16.3*	-15.7	-13.2	9.8*	1.6	6.8	8.7	9.7	10.7	12.9
Early Intermediate Period	**17**	-14.8*	0.8	-16.2	-15.4	-14.7	-14.2	-13.3	9.2*	1.1	6.9	8.8	9.1	9.7	12.0
Middle Horizon	**37**	-13.1*	1.9	-17.1	-14.3	-13.3	-11.9	-9.3	9.4*	0.8	7.5	9.0	9.6	9.9	11.0
Late Intermediate Period	**26**	-10.6	1.3	-15.3	-11.2	-10.3*	-9.8	-8.8	9.7*	1.0	8.3	9.2	9.7	10.6	12.3

Table 6.11 Summary of tooth isotopic data by time period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Period	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
Early Horizon	**6**	-16.0*	0.8	-16.6	-16.5	-16.3	-15.5	-14.7	10.5*	1.0	8.7	10.2	10.4	11.3	11.8
Early Intermediate Period	**5**	-14.8*	1.2	-16.5	-15.2	-14.7	-14.3	-13.3	8.7*	1.0	7.7	8.3	8.6	8.7	10.4
Middle Horizon	**31**	-13.8*	1.8	-16.9	-15.1	-14.1	-12.4	-10.6	9.7*	0.8	7.4	9.2	9.8	10.3	10.8
Late Intermediate Period	**18**	-10.9*	1.4	-14.6	-11.5	-10.6	-10.1	-9.2	9.8*	0.8	8.4	9.2	9.8	10.5	11.4

Table 6.12 Summary of the isotopic results from the skin samples by time period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Period	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
Early Horizon	**1**	-13.7							12.2						
Middle Horizon	**8**	-13.7*	1.1	-15.3	-14.4	-13.6	-12.9	-12.1	12.5*	0.9	11.5	11.7	12.3	13.1	14.1
Late Intermediate Period	**10**	-10.2*	1.1	-11.4	-11.0	-10.4	-9.8	-7.8	12.7*	1.3	10.8	11.8	12.4	13.2	14.9

Table 6.13 Summary of the isotopic results from the hair samples by time period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Period	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
Early Horizon	**5**	-17.1*	0.7	-17.7	-17.7	-17.4	-16.4	-16.2	9.7*	1.0	8.8	8.9	9.4	10.5	11.0
Early Intermediate Period	**4**	-16.5*	1.2	-17.7	-17.4	-16.5	-15.5	-15.2	9.1*	2.3	6.9	7.1	9.0	11.1	11.5
Middle Horizon	**26**	-13.9*	1.9	-16.7	-15.6	-14.3	-12.4	-9.8	9.0*	1.2	7.0	8.2	9.0	9.6	11.9
Late Intermediate Period	**19**	-11.4*	1.4	-13.8	-12.4	-11.4	-10.5	-9.1	9.3*	1.4	7.2	8.5	9.4	9.6	13.4

6.2.2 Faunal Samples

Bone

A total of 39 bone samples were analysed from fauna and assessed using the same criteria as the human bone samples. One sample was too small to extract collagen and one had an unacceptable C:N ratio.

For the 37 acceptable bone samples the $\delta^{13}C$ values ranged from -19.1‰ to -10.7‰ and the $\delta^{15}N$ values ranged from 4.0‰ to 17.6‰. The large range in nitrogen isotopic values is caused by the presence of terrestrial herbivores, terrestrial carnivores and marine birds in the sample set. The carbon isotopic data are normally distributed but the nitrogen isotopic data are not, due to the small number of marine birds (n=3) with values above 15‰ compared to the more numerous terrestrial camelids with lower $\delta^{15}N$ values. The mean $\delta^{13}C$ value for all of the samples is -15.1 ±2.5‰ and the median is -15.3‰ with an IQR of -16.8‰ to -12.6‰. The mean $\delta^{15}N$ value is 8.1 ±2.9‰ and the median value is 7.3‰, with the first and third quartiles having values of 6.2‰ and 8.9‰ respectively.

The carbon isotopic values of the faunal remains are widely distributed in all the time periods, with the exception of the Early Intermediate Period, which only has two samples (Figure 6.10). The means are fairly similar across the time periods, ranging from -15.8‰ (Middle Horizon) to -14.3‰ (Early Horizon). The standard deviations are large (even when excluding the Early Intermediate Period, which includes the marine birds), ranging from ±2.3‰ to ±2.8‰ (Table 6.17). The spread of the data is interesting in terms of the types of animals which make up the sample in each time period. The spread in the Early Horizon (-14.3 ±2.5‰) reflects the presence of both camelids and marine birds in the sample, whereas the Middle Horizon and Late Intermediate Period data are comprised of mostly camelids, with one other animal (dog or fox) and yet has a similar range. Thus the distribution of the data is more complex than at first glance, and is detailed to a greater level according to animal species or family in Chapter 8.

The nitrogen isotope values are quite diverse across the four time periods, reflecting the trends seen in the carbon data. The averages are fairly similar for the Early Horizon (median = 7.3‰), Middle Horizon (mean = 7.1‰) and Late Intermediate Period (mean = 7.0‰). The spread of the data for the Early Horizon is quite large (minimum = 4.0‰, maximum = 17.6‰) due to the presence of the marine birds, although the IQR is much tighter between

6.8‰ to 10.6‰. The spread of the Middle Horizon and Late Intermediate Period data are very similar, with standard deviations of ±1.1‰ and ±1.4‰ respectively.

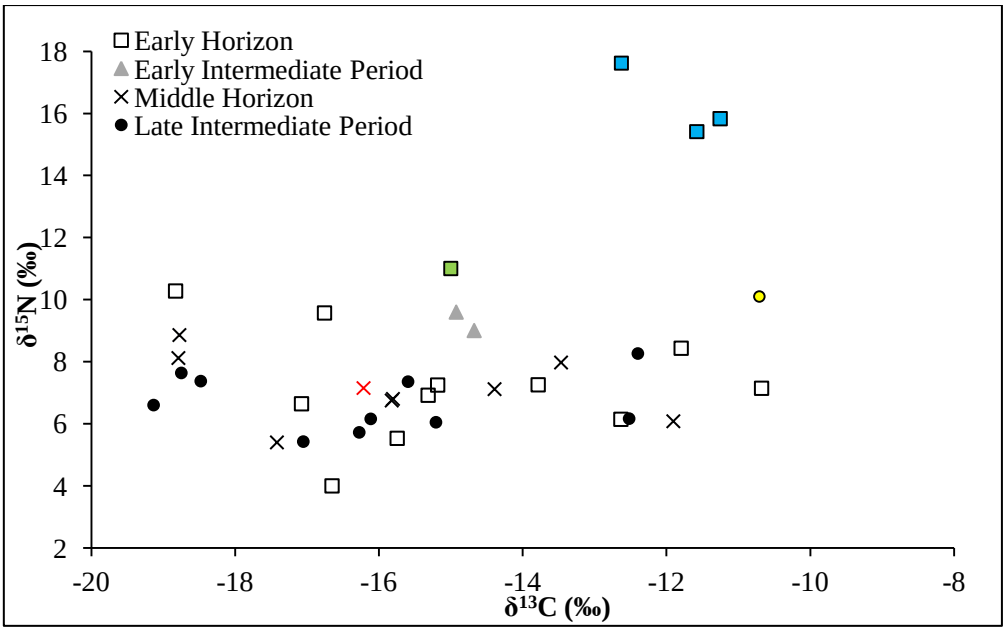

Figure 6.10 Bone collagen data from faunal samples. Blue symbols represent birds (n=3); green symbols rodent (n=1)s; yellow symbols dogs (n=1); red symbols foxe (n=1)s. The remaining symbols represent camelid data.

Tooth

Five tooth samples were run and assessed according to the same criteria as the human collagen for tooth samples. All produced acceptable results.

The $\delta^{13}C$ values, which are normally distributed, range from -17.0‰ to -15.3‰. The $\delta^{15}N$ values, which are not normally distributed, range from 8.2‰ to 10.6‰. The mean $\delta^{13}C$ value is -16.2 ±0.6‰. The median $\delta^{15}N$ value is 8.8‰, with first and third quartiles of 8.7‰ and 8.9‰ respectively.

As only one or two tooth samples per time period were run it is difficult to make much of the relationship of the values to one another. The carbon values all fall within 2‰ of one another from -17.0‰ to -15.3‰, likewise the nitrogen ranges from 8.2‰ to 10.6‰ (Table 6.18). The carbon values are similar to the means of the bone data, although the nitrogen are on the whole slightly higher (Figure 6.11).

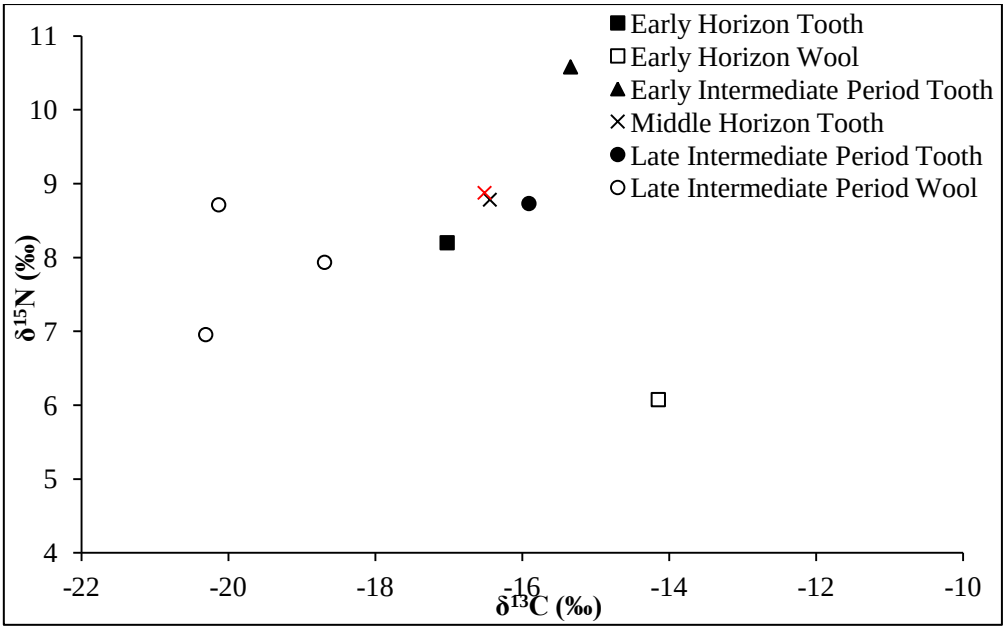

Figure 6.11 Tooth and wool data from faunal species. All are camelids except for the red symbol, which is a fox.

Wool

Four wool samples were analysed and judged by the same criteria as human hair samples. They all produced acceptable results. The data from all of the wool samples are normally distributed for both carbon and nitrogen. The carbon values range between -20.3‰ and -14.2‰ and the nitrogen values between 6.1‰ and 8.7‰. The mean $\delta^{13}C$ value is -18.3 ±2.9‰ and the mean $\delta^{15}N$ value is 7.4 ±1.1‰.

Only two time periods are represented by wool values due to small sample sizes. The Early Horizon value for carbon (-14.2‰) is quite different from the Late Intermediate Period mean of -19.7 ±0.9‰ (Table 6.19). This does not reflect the values seen in the other tissue types but due to the small sample size this observation should be taken with caution. The nitrogen values are closer, with the Early Horizon value of 6.1‰ and the Late Intermediate Period mean 7.9 ±0.9‰. These are in the region of what has been observed in the other tissues (Figure 6.11).

These results can be further broken down by time period and by cemetery as detailed in Tables 6.14 to 6.19. An asterisk (*) indicates which measure of average is more suitable based on whether the data were normally distributed (mean) or not normally distributed (median).

Table 6.14 Summary of faunal bone isotope results for each cemetery. Cemeteries 1001, 1002 and 1004 date to the Early Horizon; Cemetery 734 to the Early Intermediate Period; Cemeteries 398 and 755 to the Middle Horizon; and Cemetery 1003 to the Late Intermediate Period.

		δ^{13}C (‰)							δ^{15}N (‰)						
Cem.	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
1001	**2**	-14.0	1.9	-15.3	-15.3	-14.0	-12.6	-12.6	6.5	0.5	6.2	6.2	6.5	6.9	6.9
1002	**3**	-14.4*	3.3	-16.8	-16.2	-15.7	-15.7	-10.7	7.4*	2.0	5.5	6.3	7.2	8.4	9.6
1004	**10**	-14.4*	2.6	-18.8	-16.7	-14.4	-11.8	-11.3	10.4*	4.5	4.0	7.3	9.4	15.4	17.6
734	**2**	-14.8	0.2	-14.9	-14.9	-14.8	-14.7	-14.7	9.3	0.4	9.0	9.0	9.3	9.6	9.6
398	**2**	-16.0	0.3	-16.2	-16.2	-16.0	-15.8	-15.8	7.0	0.2	6.8	6.8	7.0	7.2	7.2
755	**7**	-15.8*	2.7	-18.8	-18.1	-15.8	-13.9	-11.9	7.2*	1.2	5.4	6.4	7.1	8.1	8.9
1003	**11**	-15.7*	2.8	-19.1	-17.8	-16.1	-13.9	-10.7	7.0*	1.4	5.4	6.1	6.6	7.5	10.1

Table 6.15 Summary of tooth isotopic results from faunal samples for each cemetery. Cemetery 1004 dates to the Early Horizon; Cemetery 734 to the Early Intermediate Period; Cemetery 398 to the Middle Horizon; and Cemetery 1003 to the Late Intermediate Period.

		δ^{13}C (‰)							δ^{15}N (‰)						
Cem.	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
1004	**1**	-17.0							8.2						
734	**1**	-15.3							10.6						
398	**2**	-16.5	0.0	-16.5	-16.5	-16.5	-16.4	-16.4	8.8	0.1	8.8	8.8	8.8	8.9	8.9
1003	**1**	-15.9							8.7						

Table 6.16 Isotopic results summary for all faunal wool samples by cemetery. Cemetery 1001 dates to the Early Horizon and Cemetery 1003 to the Late Intermediate Period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Cem.	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
1001	**1**	-14.2							6.1						
1003	**3**	-19.7*	0.9	-20.3	-20.2	-20.1	-19.4	-18.7	7.9*	0.9	7.0	7.4	7.9	8.3	8.7

Table 6.17 Faunal bone isotopic results summary by time period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Period	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
Early Horizon	**15**	-14.3*	2.5	-18.8	-16.2	-15.0	-12.2	-10.7	9.3	4.0	4.0	6.8	7.3*	10.6	17.6
Early Intermediate Period	**2**	-14.8	0.2	-14.9	-14.9	-14.8	-14.7	-14.7	9.3	0.4	9.0	9.0	9.3	9.6	9.6
Middle Horizon	**9**	-15.8*	2.3	-18.8	-17.4	-15.8	-14.4	-11.9	7.1*	1.1	5.4	6.8	7.1	8.0	8.9
Late Intermediate Period	**11**	-15.7*	2.8	-19.1	-17.8	-16.1	-13.9	-10.7	7.0*	1.4	5.4	6.1	6.6	7.5	10.1

Table 6.18 Summary of tooth isotopic results for faunal samples by time period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Period	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
Early Horizon	**1**	-17.0							8.2						
Early Intermediate Period	**1**	-15.3							10.6						
Middle Horizon	**2**	-16.5	0.0	-16.5	-16.5	-16.5	-16.4	-16.4	8.8	0.1	8.8	8.8	8.8	8.9	8.9
Late Intermediate Period	**1**	-15.9							8.7						

Table 6.19 Summary of faunal wool isotopic results by time period.

		$\delta^{13}C$ (‰)							$\delta^{15}N$ (‰)						
Period	**n**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**	**Mean**	**1σ**	**Min.**	**1st Quartile**	**Median**	**3rd Quartile**	**Max.**
Early Horizon	**1**	-14.2							6.1						
Late Intermediate Period	**3**	-19.7*	0.9	-20.3	-20.2	-20.1	-19.4	-18.7	7.9*	0.9	7.0	7.4	7.9	8.3	8.7

6.2.3 Plant Samples

Twenty-eight archaeological plants were analysed for their carbon isotope ratio. The quality of the results was assessed on the peak size of the sample in comparison to that produced by the alanine standard and the reproducibility of isotope value for each sample.

All of the samples produced peak sizes within the correct range (half to double that of the alanine standard). However, seven samples did not give reproducible results between the two duplicates, with differences between the $\delta^{13}C$ values >0.3‰. For one sample (*Psidium guajava*), there was only sufficient material for one sample to be run and therefore the value should be taken with caution.

The modern and archaeological plants show good agreement in their carbon isotope results except in one case (Table 6.20). As the modern plants were collected between 2002 and 2008, they are expected to be approximately 1.5‰ lower than their archaeological counterparts due to the fossil fuel effect (Long *et al.* 2005). Generally the modern plant values are lower than the archaeological samples, although the standard deviations show there to be a wide range in the modern values. The effects of the local environment in which the plant grows can have an effect on the isotope values of up to 5‰ (Körner *et al.* 1988; Sparks and Ehleringer 1997; van de Water *et al.* 2002; Vitousek *et al.* 1990; Vitousek *et al.* 1988; Wang *et al.* 2008), which will potentially obscure the fossil fuel effect.

The archaeological grass sample of *Gynerium sagittatum* has produced an unexpected value given that of the modern sample. The modern sample originated from the Herbarium at the Royal Botanic Gardens, Kew, and therefore the identity of the sample is taken as being accurate. Therefore the most parsimonious explanation is that the archaeological specimen was misidentified, as both C_3 and C_4 grasses have been identified on the south coast (Cadwallader *et al.* 2012).

For the specimens not identified to species level it is difficult to ascertain how well they correspond to what would be expected, given modern values, due to the isotopic variability within a plant genus. It has been shown that some genera have both C_3 and C_4 species and therefore giving a mean or range for modern plants analysed may be misleading if it does not include all species in that genus. The specimens sampled at the genus level do conform to what would be expected in terms of C_3 and C_4 plants where only one photosynthetic pathway is known for the genus.

Table 6.20 Isotopic results of the archaeological plants samples analysed and isotopic values from modern plants for comparison. Modern means have not been corrected for the Suess effect.

	Archaeological specimen (n=28)			**Modern mean from Cadwallader *et al.* (2012)**	
Sample	**$\delta^{13}C$ (‰)**	**Difference in $\delta^{13}C$ between replicates (‰)**	**No. of replicates**	**$\delta^{13}C$ (‰)**	**1σ (‰)**
Zea mays	-10.7	0.2	2	-11.8	1.4
Gynerium sagittatum	-10.6	0.0	2	-26.5	
Psidium guajava	-27.0		1	-27.1	
Phaseolus vulgaris	-24.2	0.1	2	-25.1	1.2
Lagenaria siceranea	-24.0	0.2	2	-25.1	
Manihot esculenta	-22.8	0.1	2		
Canna edulis	-22.3	0.0	2		
Phaseolus lunatus	-22.0	0.2	2	-23.8	1.6
Inga sp.	-25.0	0.1	2		
Inga sp.	-23.7	0.2	2		
Prosopis sp.	-24.4	0.1	2		
Phragmites sp.	-24.1	0.1	2		
Capsicum sp.	-23.4	0.1	2		
Gossypium sp.	-23.0	0.0	2		
Cucurbita sp.	-22.6	0.2	2		
Cucurbita sp.	-22.4	0.1	2		
Cenchrus sp.	-13.7	0.1	2		
Poaceae	-12.0	0.1	2		
Cyperaceae	-12.0	0.1	2		
Cyperaceae	-11.6	0.0	2		
Discarded Samples					
Zea mays	-10.3	0.4	2		
Crotalaria sp.	-22.4	0.4	2		
Arachis hypogaea	-32.6	17.3			
Portulaca oleraceae	-17.7	4.5			
Amaranthus sp.	-17.3	0.5			
Salix sp.	-25.8	1.7			
Amaranthaceae	-15.7	2.1			
Poaceae	-28.2	2.0			

6.3 Results Summary

In summary, the human samples collected represent all ages and sex, although to a varying degree largely due to the skeletal elements available for osteological (and hence isotopic) analysis. A wide range of pathological conditions were observed in the skeletal samples, with

dental pathologies the most common. There was no particular association between the time period and pathologies observed, which is likely to be due to the incomplete nature of the remains for each individual. The human isotopic data show an increasing $\delta^{13}C$ signal over time, with relatively constant $\delta^{15}N$ values.

The camelid isotopic results do show some variation among the cemeteries in terms of $\delta^{15}N$ values. The carbon isotopic values of these animals are widespread suggesting a difference in fodder for animals of the same age. The marine birds that were isotopically analysed have values that fit well with the expected marine isotopic signal. The archaeological plants analysed agree well with modern specimens, which suggests little diagenesis has occurred. However, the identification of one archaeological plant specimen has been called into question based on the carbon isotope result.

Chapter 7 Tissue Spacing - Results and Discussion

This chapter examines the isotopic relationship between the four different tissues analysed and how they can be used to understand life histories. As detailed in Chapter 4, the tooth data represent a childhood dietary signal, bone an adult average, and skin and hair the last months of life. I look first at the data from a population level, examining the isotopic breadth of the population over the course of the lifetime. Secondly I investigate whether it is possible to examine each individual in depth through the relationship of one tissue to another and how well this compares to the expected tissue relationships based on published isotopic feeding studies.

7.1 Population Level Lifetime Dietary Trends

Previous life history studies through isotopic analysis have either conducted broad analyses of life histories at the population level looking at diet and social reasons for change (Turner *et al.* 2010; Williams 2005) or individual migration histories using the same tissue type from samples formed at different life stages, e.g. bone from femur versus rib (Sealy *et al.* 1995) or dentine from successive molars (Turner *et al.* 2010). Life history analysis using several isotopes (C, N, O and Sr) of bone and teeth has also been used to successfully identify first generation slaves who moved from Africa to Barbados (Schroeder *et al.* 2009). These broad approaches have been successful but do not offer a close inspection that may reveal how social, economic or environmental factors induced dietary changes that directly impacted on the life of an individual. No study has analysed four tissues from the same individual, as undertaken in this research.

Using a similar method of analysis to these published studies, I have examined the distribution of $\delta^{13}C$ and $\delta^{15}N$ values of the four tissue types as a measure of the changing isotopic breadth over the course of the population lifetime. In order to achieve this the data have been binned, i.e. grouped into separate smaller ranges, allowing the data to be plotted in a frequency diagram.

A comparison of all individuals studied in this thesis for each of the different tissue types enables a broad comparison in the breadth of the isotopic ranges at different life stages. This will facilitate the identification of dietary changes that were common to the population, and

therefore are likely to have some social or political significance. For example an isotopic shift between the tooth and bone data would suggest a dietary change occurred sometime between the formation of the two tissues, i.e. between childhood and adulthood. This timing, albeit a broad one, and the nature of the isotopic shift would feed into ideas of how food was used socially as a tool for marking identities.

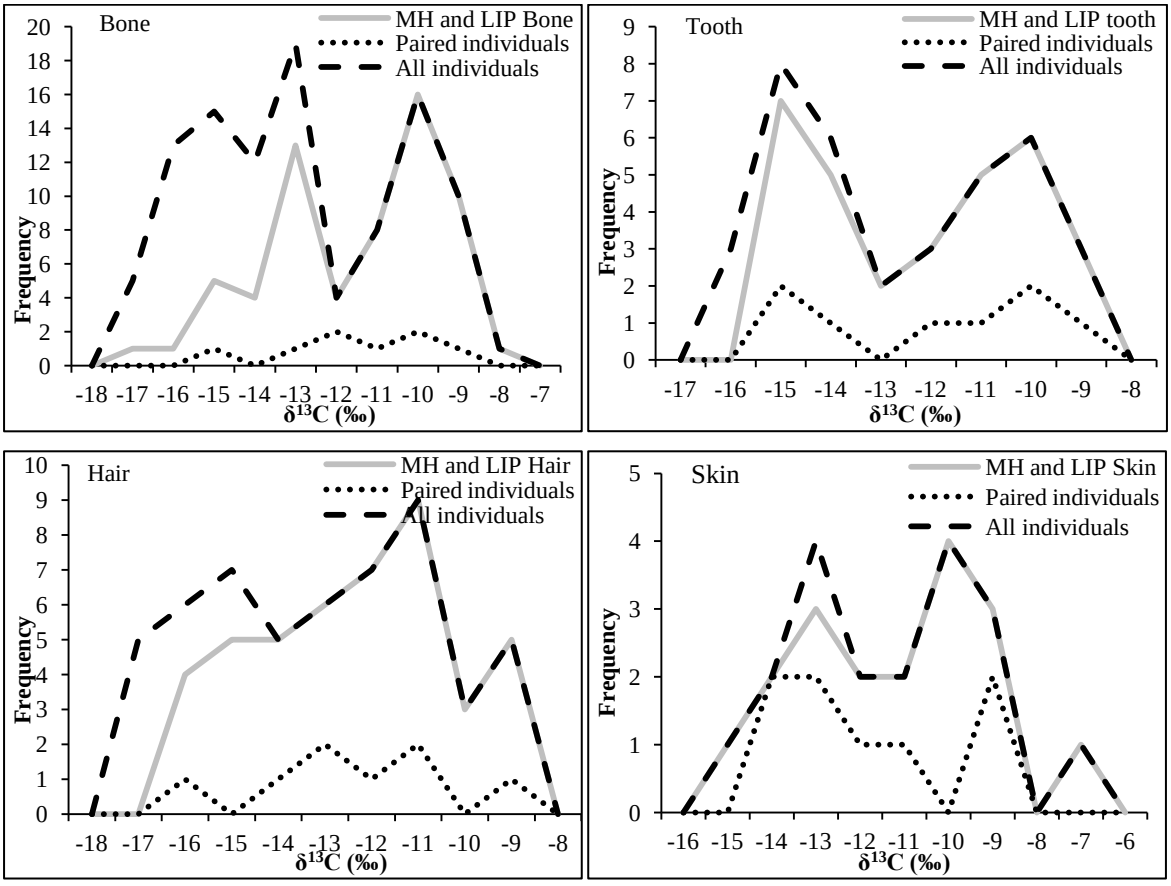

Figure 7.1The distribution of carbon isotope values using different sets of individuals - all, paired and Middle Horizon and Late Intermediate Period together. The' paired individuals' data refer to those individuals for whom all four tissue types were analysed (n=8).

The tissue samples examined in this research are not equally distributed in terms of chronology, with the majority of skin and hair samples coming from the two later time periods. Comparing the isotopic distribution curves of individuals analysed from all time periods to only the individuals from the Middle Horizon and Late Intermediate Period, a striking difference can be seen in the shape of the distribution curves (Figure 7.1). Whilst the

tooth, skin and hair curves based on all the individuals show good agreement when compared to the curved based only on the Middle Horizon and Late Intermediate Period data, the bone distribution curves based on these two subgroups do not. The inclusion of all individuals creates a distribution with more individuals with lower $\delta^{13}C$ values. These individuals belong to the earlier two periods (Early Horizon and Early Intermediate Period), whereas they are largely absent from the other three tissue types. Thus their inclusion in the distribution curves would result in a misleading comparison of the four tissue types. Ideally only those individuals with paired data, i.e. multiple tissue types, would be used for this type of analysis but only eight individuals out of 120 satisfy this criteria for all four tissue types.

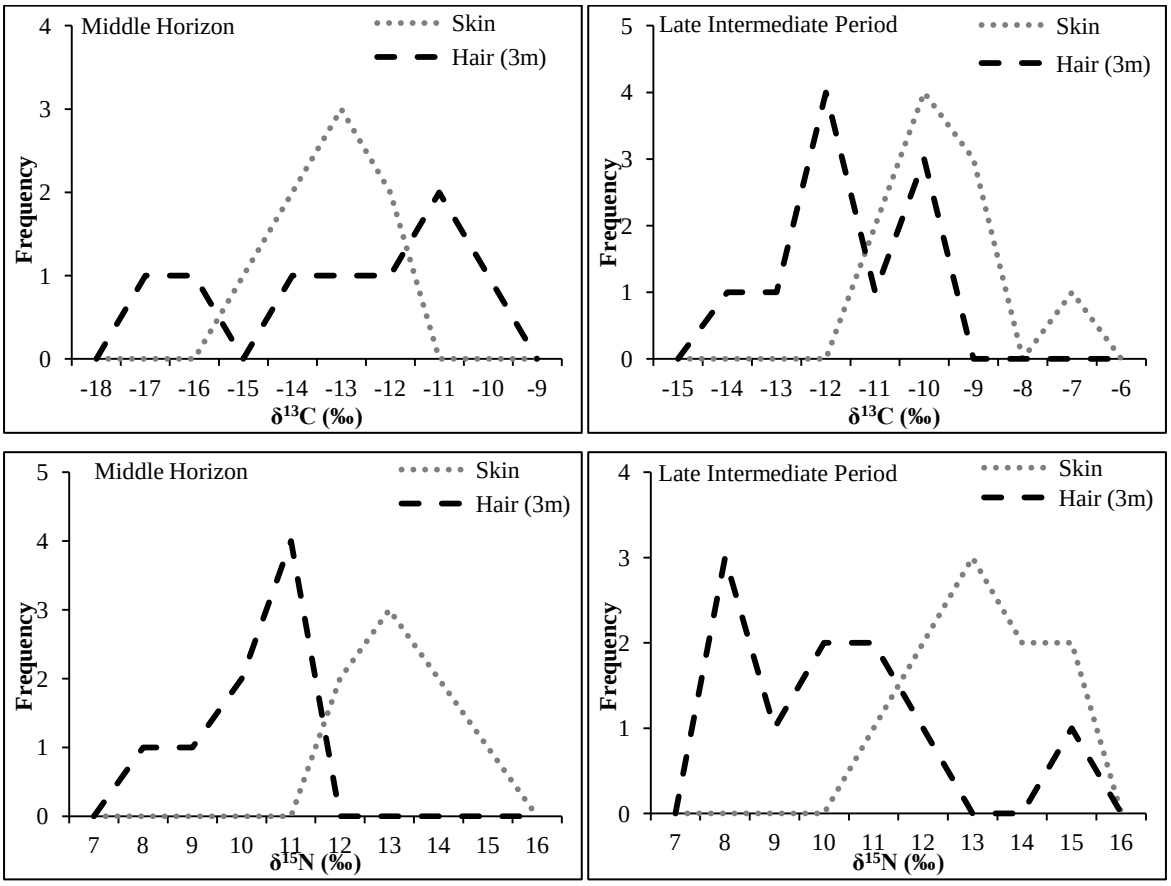

Figure 7.2 Distribution of skin and proximal hair data for Middle Horizon and Late Intermediate Period individuals. Clockwise from top left: a) Middle Horizon carbon isotope data; b) Late Intermediate Period carbon isotope data; c) Late Intermediate Period nitrogen isotope data; d) Middle Horizon nitrogen isotope data.

When examining just the later individuals from the Middle Horizon and Late Intermediate Period it is clear that there is a bimodal distribution in the carbon results in the bone, tooth and to some extent the hair data, roughly equating to a C_3 and a C_4 diet (Figure 7.2). This dietary dichotomy has important implications for the interpretation of the factors influencing dietary choice. Plotting the data by time period clearly shows that this issue affects just the Middle Horizon population and therefore it is vital that the analysis of life history at this level is conducted for each separate time period. However, sample sizes will limit the strength of any conclusions drawn in some cases. Where possible comparison of the distributions of paired tissue data, i.e. data from multiple tissues from the same individual, should enable a stronger interpretation of life histories as the background noise is reduced, yet this creates additional problems. Skin and the proximal three months of hair should be comparable in their distributions as they represent the same time period. However, poor agreement between the distributions is seen in all of the time periods for which these data are available (Figure 7.2).

If an attempt were made to discuss the relationship of the diet at the end of life to that in an earlier phase of life (e.g. that represented by the tooth or bone data) then different conclusions would be drawn depending on whether hair or skin were used. The discrepancy between the distribution of the two tissues suggests that our understanding of the formation or synthesis of skin and/or hair is not complete. This issue is discussed in more detail in Section 7.2.

In the following examination of distributions by time period, the hair distributions will be composed using the mean isotope values from all the segmented samples. This should make the data more comparable to bone, as both will be, in general, an averaged dietary signal, although this will depend on the total length of the hair and how much of an annual cycle it represents. The hair isotope values will not be adjusted to compensate for the inherent differences between collagen and keratin. They are expected to be in the region of 1‰ lower than collagen for both carbon and nitrogen (this exact relationship is examined in more detail in Section 7.2.3). Skin samples will only be used at the whole population level as its relationship to the other tissues is not fully understood and therefore a comparison of paired data may be misleading.

In summary, the distributions should be useful in revealing:

1) broad population level dietary trends between and within infancy (tooth), adulthood (bone and hair) and last months of life (skin);

2) any specific dietary change between infancy (tooth) and adulthood (bone or hair data) using paired data;

3) any specific dietary change throughout adult life comparing paired bone (long term average) and hair (shorter term average) data.

The meaning of any variations in isotopic values seen will be discussed in the context of the archaeology in Chapters 8 and 9.

7.1.1 Early Horizon Population Distribution Curves

Due to the small sample size of tooth, skin and hair (n=4, 5 and 1 respectively) it is difficult to draw any meaningful comparisons between the different types of data for the Early Horizon.

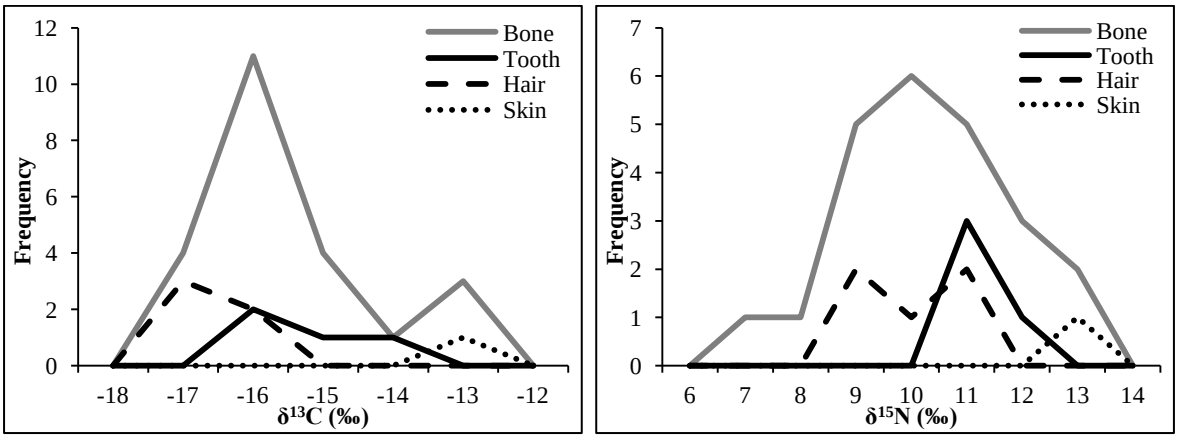

Figure 7.3 Distribution of isotopic values for all tissues analysed from the Early Horizon cemeteries, left, carbon isotopes, right, nitrogen isotopes.

The bone data (n=23) for both carbon and nitrogen isotopes encompass a wider range of values than the other tissues (Figure 7.3) but this may reflect sample size. The carbon isotopic distribution curves for all the tissues are similar in that they are predominantly C_3 based with the exception of one individual who records a higher $\delta^{13}C$ binned value in both bone and skin (both -13‰) but has a slightly lower value (-14‰) from the dentine. Nitrogen isotope values in bone show a much wider spread than all the other tissues. The majority of individuals plotted in the range of 8‰ to 12‰ for bone, hair and teeth. The distributions indicate that the intra-population isotopic range increased from infancy to adulthood.

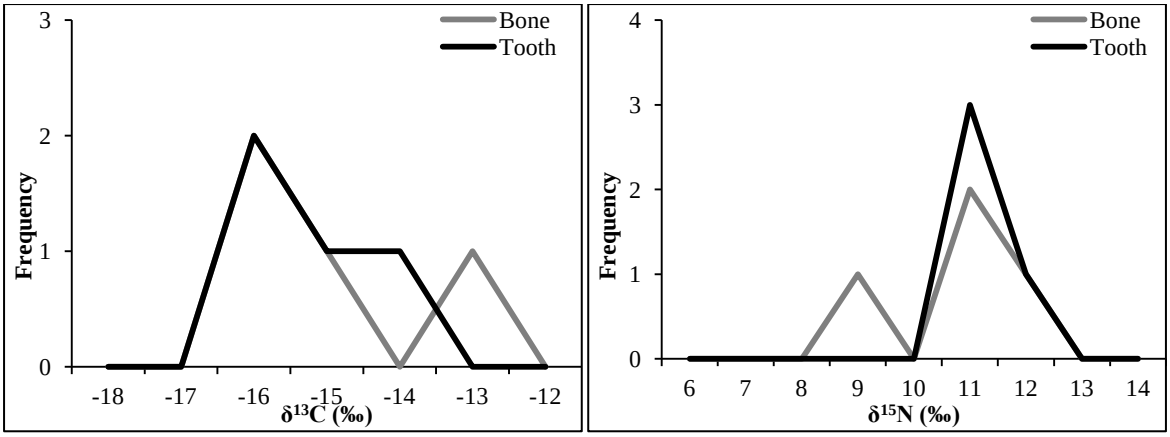

Figure 7.4 Paired bone and tooth data from the Early Horizon individuals with both tissue analysed, left carbon isotopes, right nitrogen isotopes.

The isotopic distributions of the Early Horizon individuals for whom there exists both bone and tooth data (n=4) suggest that isotopic values of the dietary inputs for the majority did not change between infancy and adult life, although there is a slight widening in both carbon and nitrogen isotope ranges (Figure 7.4), supporting what is observed in the general trends.

7.1.2 Early Intermediate Period Population Distribution Curves

This period likewise suffers from very small sample sizes (bone n=17, tooth n=5, hair n=4) and a complete lack of data from skin samples and as such it is very difficult to comment on the life histories of the Early Intermediate Period population.

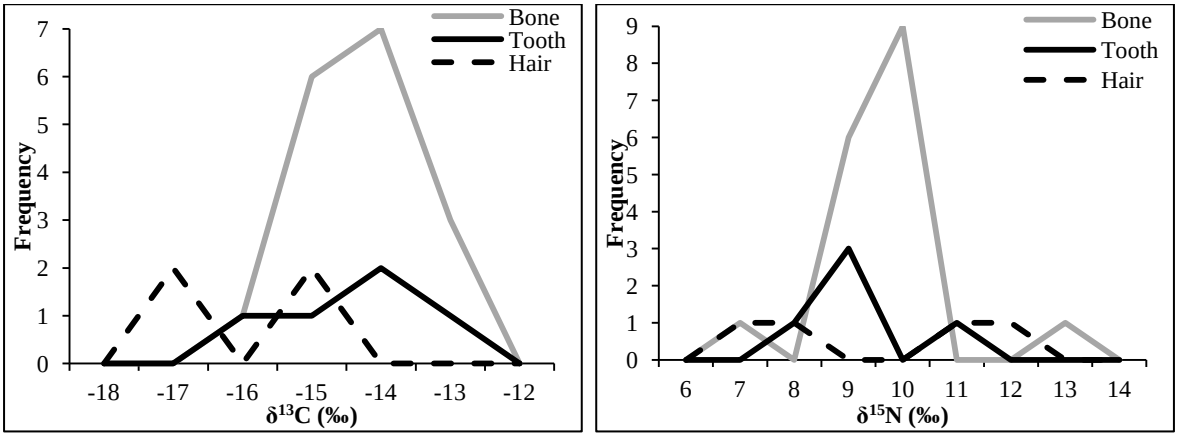

Figure 7.5 Distribution of isotopic values for all tissues analysed from the Early Intermediate Period cemetery, left, carbon isotopes, right, nitrogen isotopes.

The carbon isotopic data available suggest that resources with similar isotopic values were on the whole being exploited by all individuals throughout their lifetimes (Figure 7.5). There is a wide spread in nitrogen isotopic data in all the tissues, although the tooth data have a slightly narrower range than the other tissues suggesting a possible widening of protein resources in later life.

The paired bone tooth data from individuals with both tissues analysed (n=5) present a contrary view of the life history between infancy and average life. They suggest a narrowing of carbon isotopic resources in later life, whereas nitrogen remains largely the same (Figure 7.6).

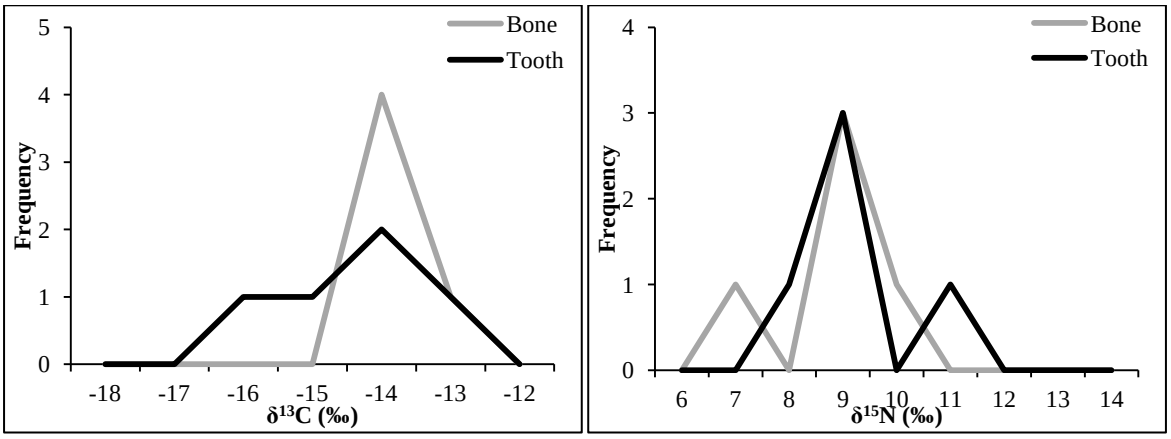

Figure 7.6 Paired bone tooth isotopic data from Early Intermediate Period individuals with both tissues analysed, right, carbon, left, nitrogen.

7.1.3 Middle Horizon Population Distribution Curves

A bimodal split in the carbon isotope results is evident in the bone, hair and tooth data (Figure 7.7) in the Middle Horizon populations. All three are skewed to the left, i.e. more negative $\delta^{13}C$ values, although the point of the split between the two groups differs. The isotopic range did not significantly change between infancy (tooth) and adulthood (bone and hair). The skin data on the other hand do not follow this pattern, forming only one group.

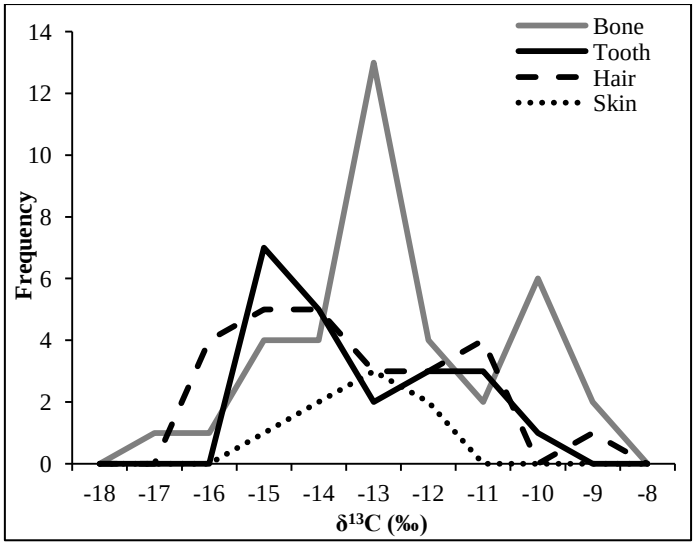

Figure 7.7 Distribution of carbon isotope values for all tissues analysed from all individuals from the Middle Horizon cemeteries.

Interestingly when only paired data (multiple tissues from one individual) are considered for $\delta^{13}C$, different distributions are seen (Figure 7.8). In the bone tooth pairings, the tooth data still display the bimodal trend with a similar range of values, skewed to the left and split at -13‰ as seen previously. However, the bone data now take on a more Gaussian distribution with the modal value at -13‰. Taken on its own the modal value of isotopic input changed between infancy and adulthood, becoming unimodal, yet the range remained constant. The tooth hair paired data are similar to that seen at the whole population level and roughly support the continued bimodality throughout life. The discrepancies between these two sets is emphasised by the bone hair pairs. The hair values suggest a wide and equal spread of individuals across the values in contrast to the bone data. However, the hair data may be affected by the length of the hair and by short-term dietary variations, which a stepwise regression shows as being a key factors in the variation of $\delta^{13}C$ values seen.

Putting more emphasis on the bone tooth data, it can be concluded that there was a general shift in the dominant carbon isotopic input in adulthood for a proportion of the population but not a decrease in range. It is unknown if those who exhibit a stronger C_4 signal in bone collagen values follow this pattern as they are underrepresented in the paired tissue data.

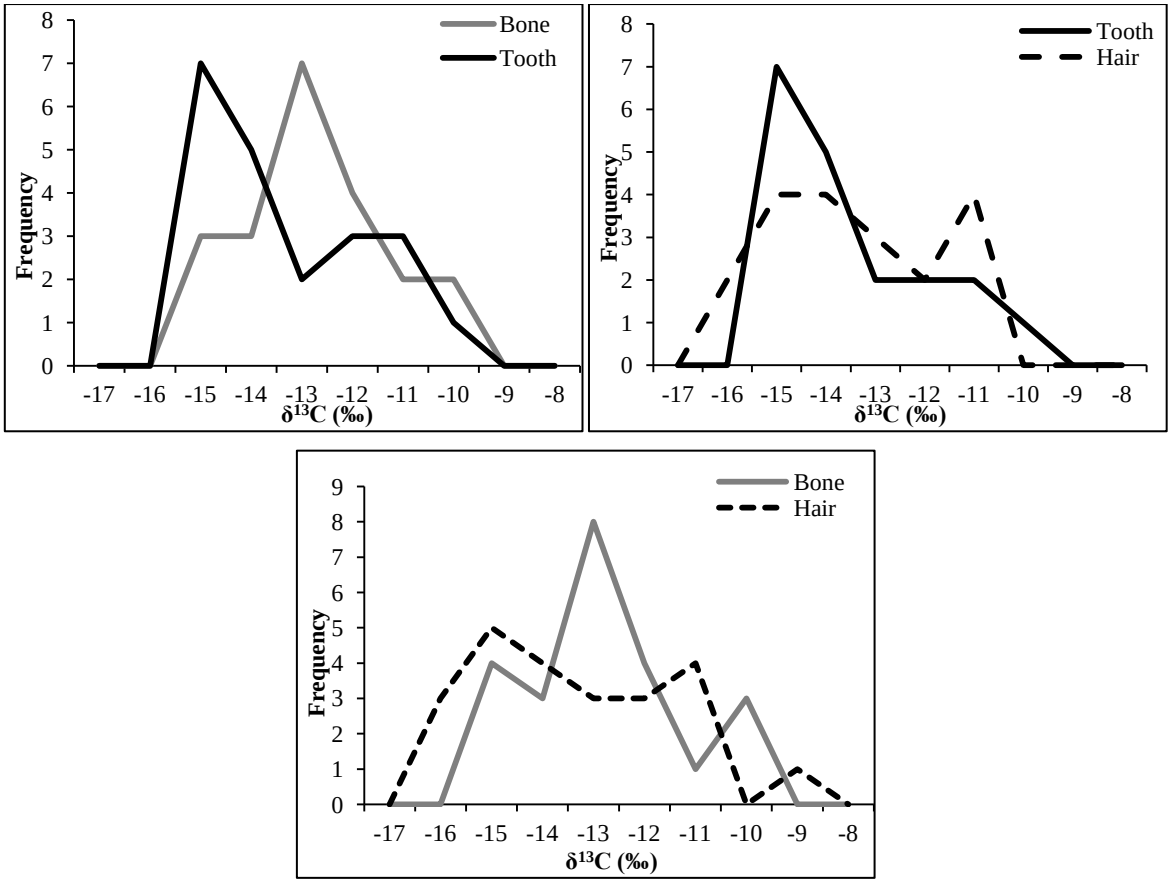

Figure 7.8 Paired carbon isotope data from Middle Horizon individuals with multiple tissue samples. Clockwise from top left: a) bone and tooth pairs; b) tooth and hair pairs; c) bone and hair pairs.

For the whole Middle Horizon population the nitrogen isotope values are broadly similar in terms of shape of distribution and magnitude for bone and hair, with the peak of the distribution differing by just 1‰ (Figure 7.9). The hair distribution is slightly skewed but this may have been caused by the effect of the hair length. The tooth data have a generally normal distribution but with a narrower range than the other tissues. Skin is elevated compared to all three but has the same range as bone and hair and a Gaussian distribution. From this it is summised that the range of isotopic values widened in adult life compared to infancy.

Examining the paired data for individuals with multiple tissue samples (Figure 7.10), the same conclusions can be drawn with the range of nitrogen isotope values larger in the later forming tissues. The hair distributions are offset compared to both bone and tooth and are much wider. This is again due to the hair length causing the variation as in many cases (10 out of 21) only part of the annual cycle has been analysed.

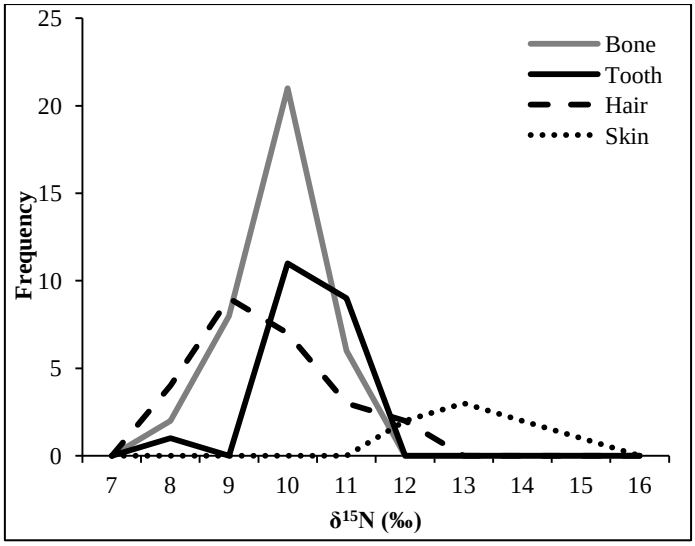

Figure 7.9 Distribution of nitrogen isotope values for all tissues analysed from all individuals from the Middle Horizon cemeteries.

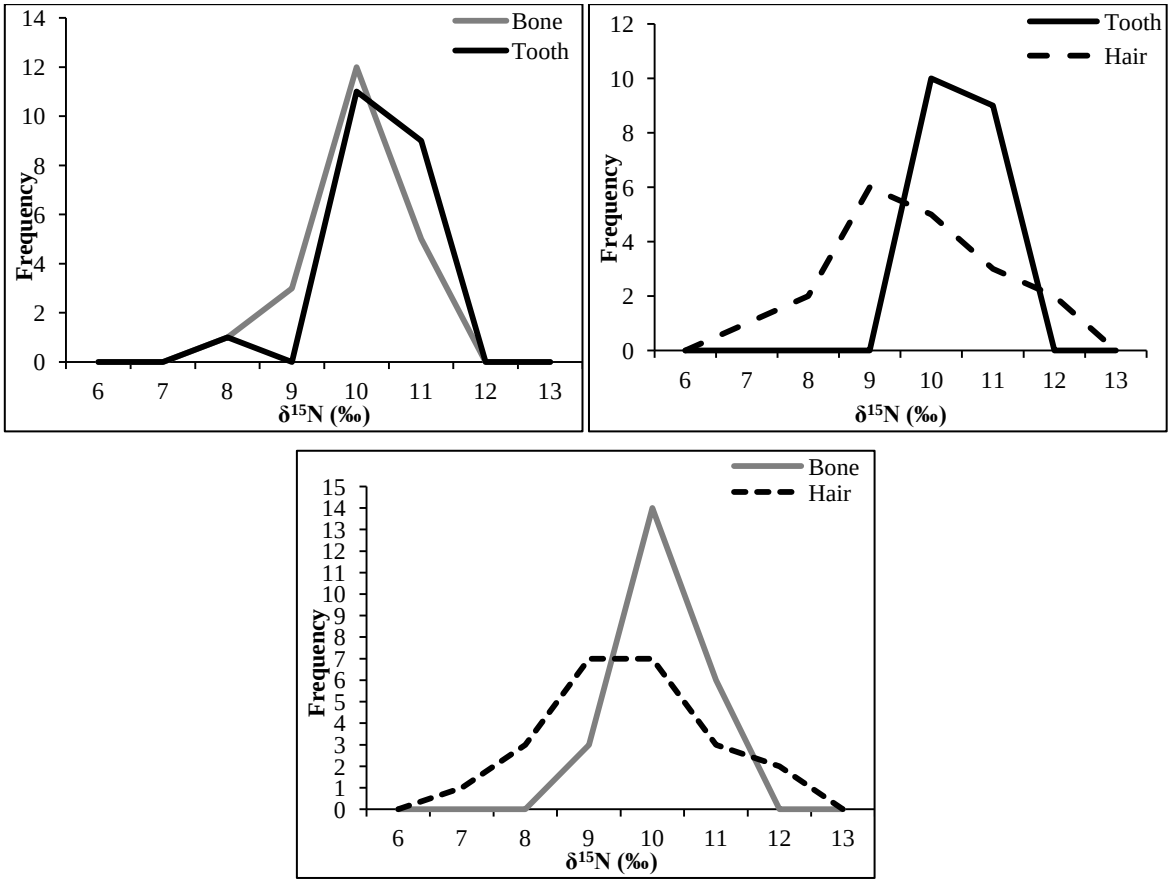

Figure 7.10 Paired nitrogen isotope data from Middle Horizon individuals. Clockwise from top left: a) Bone and tooth data; b) tooth and hair data; c) bone and hair data.

In sum, an isotopic change between infancy and adulthood can be observed in both carbon and nitrogen for the Middle Horizon. In carbon this is a move away from a bimodal distribution and in nitrogen this is a widening of isotopic values. The significance of dietary shifts shall be discussed in context of the archaeology in Chapter 8.

7.1.4 Late Intermediate Period Population Distribution Curves

The carbon isotopic distributions (Figure 7.11) for the whole Late Intermediate Period population show normal Gaussian distributions for bone, tooth and skin with two outliers (in bone and skin). The three tissues have the same ranges (excluding the outliers) and same peak values indicating that the breadth of carbon isotopic inputs was constant throughout the life of the individuals. The hair data are broader and may allude to a seasonally variant diet that included more C_3 resources.

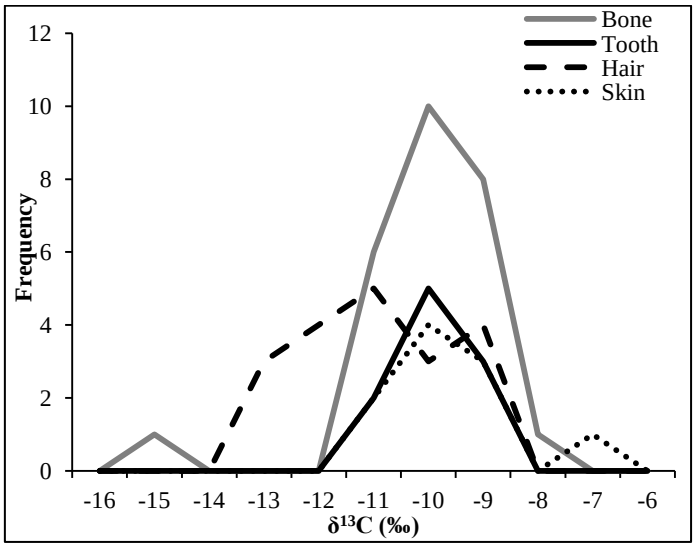

Figure 7.11 Distribution of carbon isotope values for all tissues analysed from all the Late Intermediate Period individuals.

The bone tooth paired tissue data from individuals with multiple tissue samples available (Figure 7.12) support the conclusions drawn from the whole population data. The hair distributions (Figure 7.12) are at odds with both the tooth and bone, indicating a much broader isotopic base. Again this is an effect of the hair length skewing the data recorded.

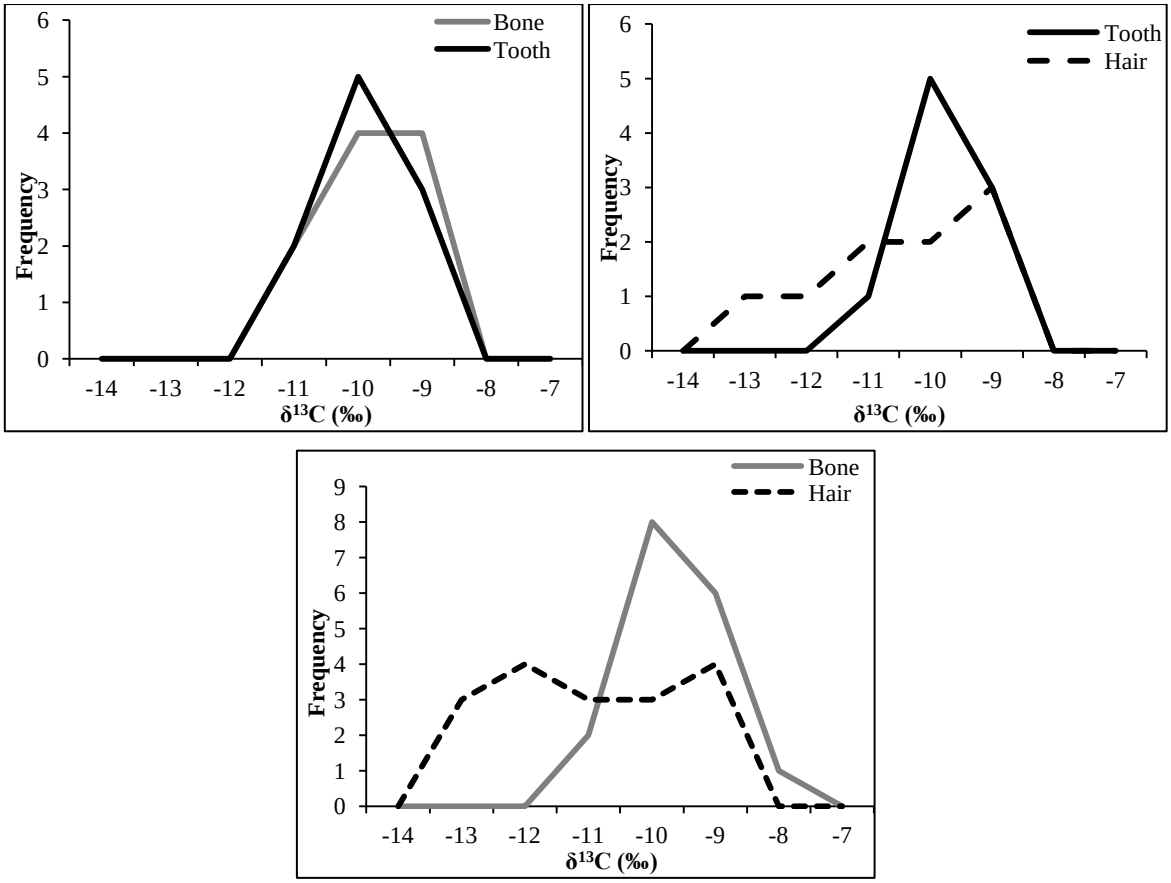

Figure 7.12 Paired carbon isotope data from Late Intermediate Period individuals with multiple tissue samples. Clockwise from top left: a) bone and tooth pairs; b) tooth and hair pairs; c) bone and hair pairs.

For nitrogen isotopes, the distributions of the whole Late Intermediate Period population are not in as close agreement as those from the carbon (Figure 7.13). The range of values is similar, with the tooth data slightly narrower than the rest. The peaks of the bone, tooth and hair data are in agreement, whereas the skin is significantly enriched - a trend common to all time periods. The bone and tooth data are slightly skewed in the same direction, whereas the hair and skin are skewed in the opposite direction. On the whole these tissues are in fair agreement with perhaps a slight change towards more individuals with lower $\delta^{15}N$ values towards the end of life.

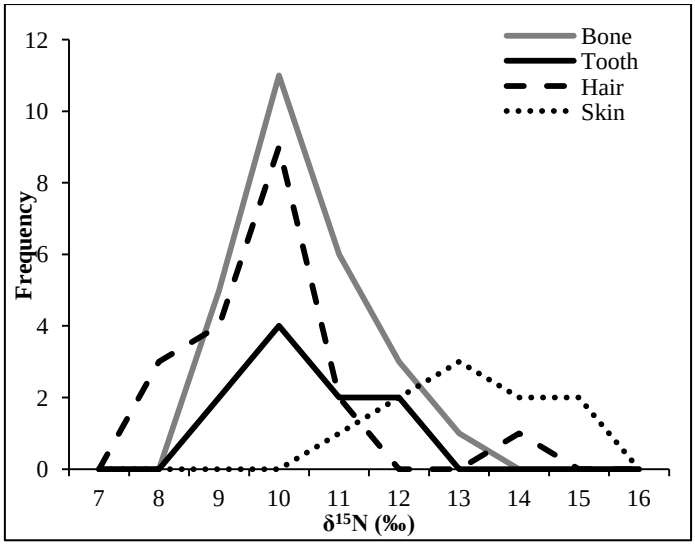

Figure 7.13 Distribution of nitrogen isotope values from all tissues from all of the Late Intermediate Period population individuals.

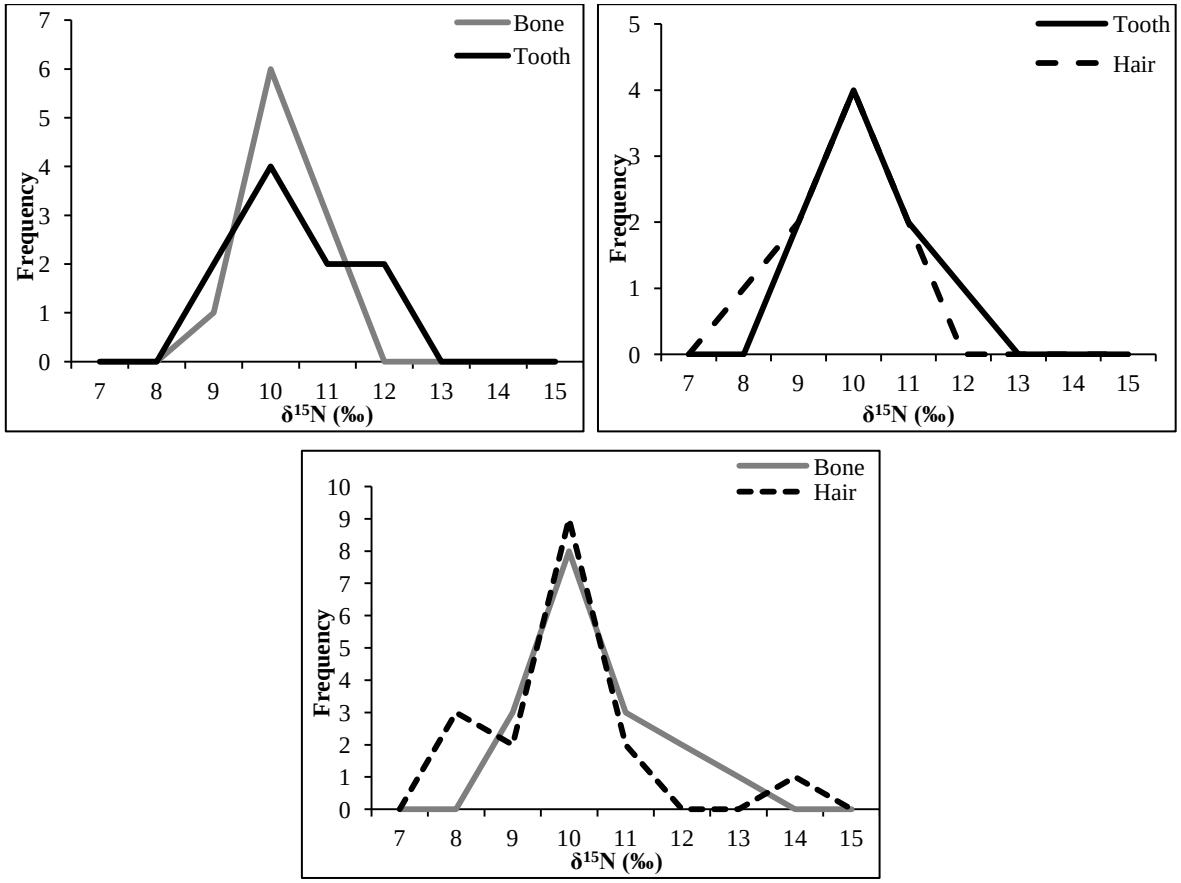

Figure 7.14 Paired tissue nitrogen isotope data from Late Intermediate Period individuals with multiple tissues available. Clockwise from top left: a) bone and tooth pairs; b) tooth and hair pairs; c) bone and hair pairs.

The paired data (Figure 7.14) on the whole agree with the overall population distributions. The tooth data do have a wider range in comparison to the paired bone data from the same individuals but not when compared to hair. The bone and hair pairs show fair agreement supporting the idea of a consistent range of isotopic inputs.

To summarise the Late Intermediate Period trends, over the life span of an individual their isotopes can be considered as constant on the whole. The population appears to be similar in terms of isotopic values, with any variation likely to be related to seasonal or monthly changes.

7.2 Individual Life History Analysis

Analysis at the population level reveals some significant dietary changes over the life of the populations, but it is unable to identify the specific individuals who underwent these transitions. The offsets between the paired tissues from individuals with multiple samples available will now be compared to the expected offset values derived from the published literature in order to identify any individuals who do not follow the expected pattern. By identifying the specific individuals who are outliers it may be possible to correlate dietary change with other factors such as age or sex or to examine any dietary changes over their life span. It should be possible to identify outliers in this way regardless of the time period that they belong to.

7.2.1 Bone-Tooth Offset

Bone and teeth are comprised of the same type of collagen. If diet has been constant throughout life, then it is reasonable to expect there to be no offset between the two tissues in both carbon and nitrogen isotopes. Bone-tooth pairs were analysed for 36 individuals.

Both bone and tooth data fit the criteria for parametric tests and are thus treated as such during statistical analyses. The mean $\delta^{13}C_{bone}$ values is -12.8 ±2.2‰ and $\delta^{15}N_{bone}$ is 9.7 ±0.9‰. The mean $\delta^{13}C_{tooth}$ values is -13.2 ±2.3‰ and $\delta^{15}N_{tooth}$ value is 9.9 ±0.8‰. The mean offset value for $\delta^{13}C_{bone\text{-}tooth}$ is 0.4 ±0.8‰ and for $\delta^{15}N_{bone\text{-}tooth}$ -0.3 ±0.5‰.

The $\delta^{13}C$ and $\delta^{15}N$ values for both tissues correlate well with each other, r= .93 (p<.001) for carbon and r= .81 (p<.001) for nitrogen. This suggests that the two tissues do have very similar isotopic values. However, a paired t-test shows both carbon and nitrogen isotopes to be significantly different between the two tissues ($t_{carbon}(35)$= 2.95, p<.05 and $t_{nitrogen}(35)$=

-2.87, $p<.05$). Although the effect size ($r_{carbon}= .45$ and $r_{nitrogen}= .44$) is fairly substantial, the 95% confidence interval of the true mean difference between the two tissues makes it clear that in terms of trophic levels the mean isotopic offset is insignificant. Based on the 95% confidence interval the mean enrichment for $\delta^{13}C_{bone\text{-}tooth}$ lies between 0.13‰ and 0.69‰, and -0.07‰ and -0.43‰ for $\delta^{15}N_{bone\text{-}tooth}$. These differences of less than 1‰ could be explained by a slight variation in the background signal of the diet and do not suggest any significant shift in the carbon or nitrogen isotopes between the time represented by the two tissues or anything structurally different between the collagen in bone or dentine. Three outliers from the population do not conform to this expectation (Figure 7.15). Given that the analysis using distribution patterns in Section 7.1 identified a shift between these two tissues in the carbon isotopes in the Middle Horizon it is surprising that only three individuals out of 36 have been deemed outliers and only one of these is from a Middle Horizon cemetery (Individual 24 - carbon outlier). The others are from the Early Horizon Cemetery 1004 (Individual 69) and Late Intermediate Period Cemetery 1003 (Individual 78).

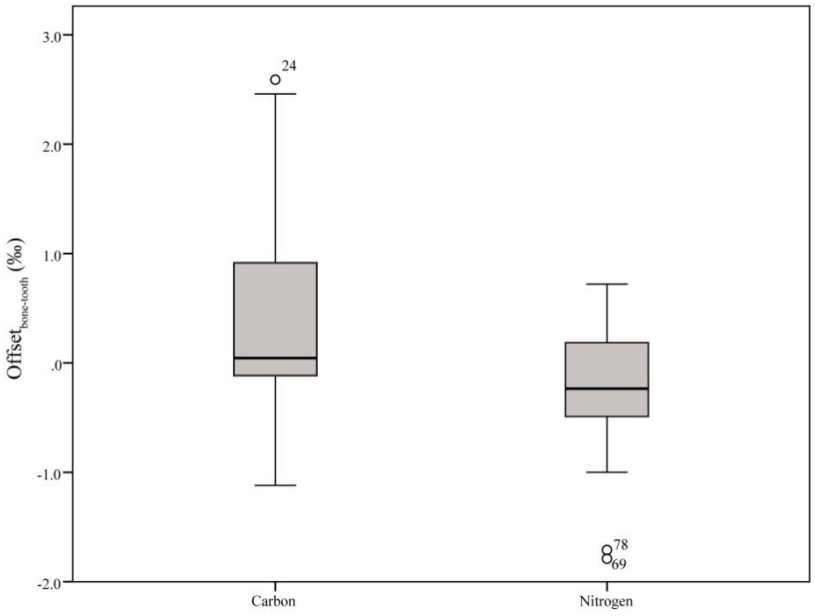

Figure 7.15 Bone tooth carbon and nitrogen isotopic offsets. Only three outliers are identified (indicated by the circles with numbers).

7.2.2 Bone/Tooth-Skin Offset

As discussed in Chapter 4, the collagen component of skin is primarily composed of the same type as bone and dentine, although with a small percentage of Type III collagen as well. As with teeth and bone, a different time period of life is represented by the skin and as such the offset should be negligible only if the diet has remained constant throughout life. Nineteen bone-skin pairs and eleven tooth-skin pairs have been analysed, all fitting the assumptions for parametric statistical tests.

Bone-Skin Pairs: For those 19 individuals where both bone and skin data are available the mean $\delta^{13}C_{bone}$ value is -11.8 ±1.9‰ and $\delta^{15}N_{bone}$ is 10.0 ±1.1‰. The mean $\delta^{13}C_{skin}$ values is -11.8 ±2.1‰ and $\delta^{15}N_{skin}$ value is 12.6 ±1.1‰. The mean offset value for $\delta^{13}C_{bone\text{-}skin}$ is -0.1 ±0.8‰ and for $\delta^{15}N_{bone\text{-}skin}$ -2.5 ±0.6‰.

Tooth-Skin Pairs: For the eleven individuals who have both tooth and skin data the mean $\delta^{13}C_{tooth}$ value is -12.8 ±2.1‰ and $\delta^{15}N_{tooth}$ is 10.0 ±0.7‰. The mean $\delta^{13}C_{skin}$ values is -12.3 ±1.8‰ and $\delta^{15}N_{skin}$ value is 12.4 ±0.9‰. The mean offset value for $\delta^{13}C_{tooth\text{-}skin}$ is -0.5 ±0.9‰ and for $\delta^{15}N_{tooth\text{-}skin}$ -2.4 ±0.5‰.

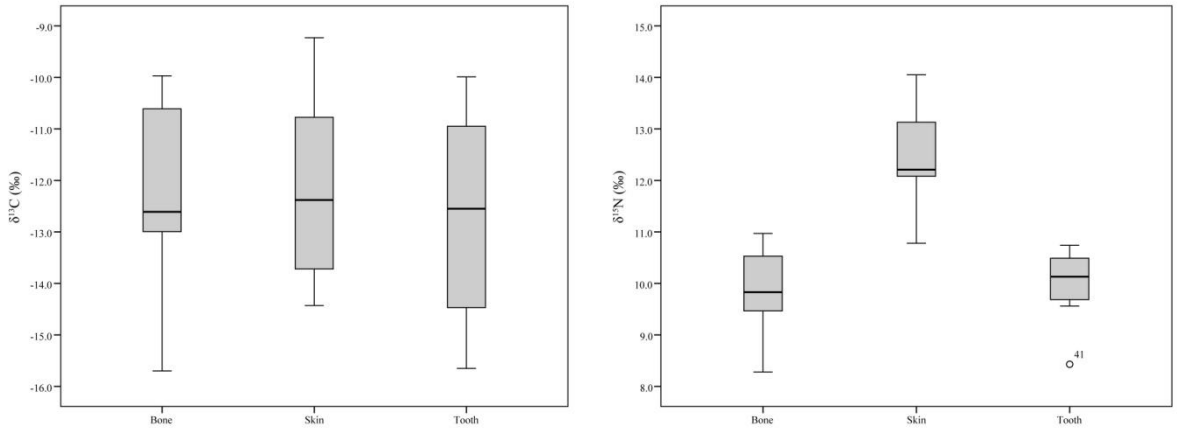

Figure 7.16 Comparison of the isotopic results from the three different tissue types for the eleven individuals with all three types analysed. Left, the carbon isotope data are similar for all three tissues; right, nitrogen isotope data for skin are markedly different from the bone and tooth data.

For the 11 individuals with all three tissues available, the statistics confirm that the carbon isotopic values are very similar between the three tissues whereas nitrogen isotopic values are

not (repeated measures ANOVA for carbon $F(2, 20)= 3.11$, $p>.05$; for nitrogen $F(2, 20)= 161.33$, $p<.001$; Figure 7.16). Applying a post-hoc Bonferroni test it is clear that the difference in $\delta^{15}N$ values is between the skin and the other two tissues ($p<.001$).

Additionally, there is no statistical difference between the offsets (bone-skin and tooth-skin) for both isotopes, whether using paired samples or all available samples for each offset (Table 7.1). Thus the magnitude of the differences between the bone and tooth compared to skin is consistent, as illustrated in the box plot (Figure 7.17).

Table 7.1 Results of statistical tests using paired bone-skin (b-s) and tooth-skin (t-s) data from the eleven individuals with all three tissues available (top half of table) and all individuals with paired bone-skin or tooth-skin data available (bottom half of table).

Paired Sample t-test (n=11)			
	t	**df**	**Sig.**
$\boldsymbol{\delta^{13}C_{offsets}}$	2.17	10	$p>.05$
$\boldsymbol{\delta^{15}N_{offsets}}$	-0.93	10	$p>.05$
Independent Sample t-test (n=19 b-s; n=11 t-s)			
$\boldsymbol{\delta^{13}C_{offsets}}$	-1.68	28	$p>.05$
$\boldsymbol{\delta^{15}N_{offsets}}$	0.50	28	$p>.5$

The results seen here are of a similar magnitude to those seen in other studies. Finucane (2007) recorded mean offsets for a sample of six Peruvian mummies from the highlands as $\delta^{13}C_{bone\text{-}skin}$ = 0.2 ±0.4‰ and $\delta^{15}N_{bone\text{-}skin}$ = -2.1 ±0.5‰, which he interpreted as being due to a dietary change between the times represented by the two tissues. Similarly in a large study of Peruvian mummies from the coast (n=40), Williams (2005) observed mean offsets of $\delta^{13}C_{bone\text{-}skin}$ = 0.2 ±1.0‰ and $\delta^{15}N_{bone\text{-}skin}$ = -3.0 ±1.1‰. In a study of Nubian mummies, results following this general trend were observed, although the means from all available samples were compared rather than just paired samples (White and Schwarcz 1994). Much larger offsets in both carbon and nitrogen isotopes were observed in Argentine archaeological samples (n=7) with mean $\delta^{13}C_{bone\text{-}skin}$ = 2.0 ±2.0‰ and $\delta^{15}N_{bone\text{-}skin}$ = -4.1 ±2.7‰ (Shelnut 2006). No explanation is offered by the author for these values. The pattern of offsets has also been observed for animal data, with carbon isotopes having little enrichment between bone

and skin but a significant enrichment in nitrogen albeit to a lesser magnitude (O'Connell unpublished).

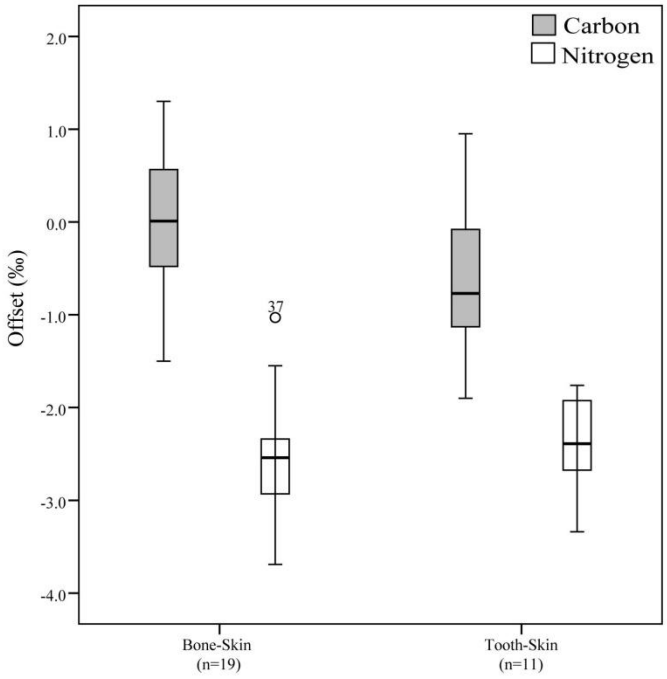

Figure 7.17 Box plot showing both carbon and nitrogen isotopic offsets for bone-skin (n=19) and tooth-skin (n=11) pairs.

Clearly there is a common trend in all of these studies - $\delta^{15}N$ value is different between bone (or tooth) and skin by approximately 2‰ and $\delta^{13}C$ is offset by a very small amount close to 0‰. This is cannot be adequately explained by a change in diet, especially since the animal data are taken from a controlled feeding study (O'Connell unpublished). A number of factors may contribute to this observed signal and these are discussed below.

Composition of tissues - Collagen Types I and III

As explained in Chapter 4 there are differences between the amino acid composition of Type I and III collagen. Type III makes up only a small proportion of collagen in skin, approximately 10% (Odland 1991; Wenstrup *et al.* 1991). Modelling of the two types of collagen has shown that the difference in amino acid composition is not enough to cause the

observed offset (M. Collins *pers. comm.*) and therefore the basic composition cannot be responsible.

Age of individual

The proportion of Type III compared to Type I collagen in skin is much higher for foetuses than in adults and therefore the proportion of these collagens has been linked to age (Epstein 1974; Smith *et al.* 1986), although this is not supported by the analysis of the amino acid composition of skin collagen (Miyahara *et al.* 1978) Furthermore, age was not seen to correlate with the $\delta^{15}N$ values of the soft tissues of different types of mussels (Minagawa and Wada 1984), suggesting that either there is no change in the composition of the collagen in the organism or that any change has no apparent effect on the isotopic value of the tissue. Ambrose (2000) found no statistically meaningful correlation between the $\delta^{15}N$ value of collagen and age of the animal. Likewise he also reports little observed increase in $\delta^{13}C$ with age contrary to findings by Ambrose and Norr (1993).

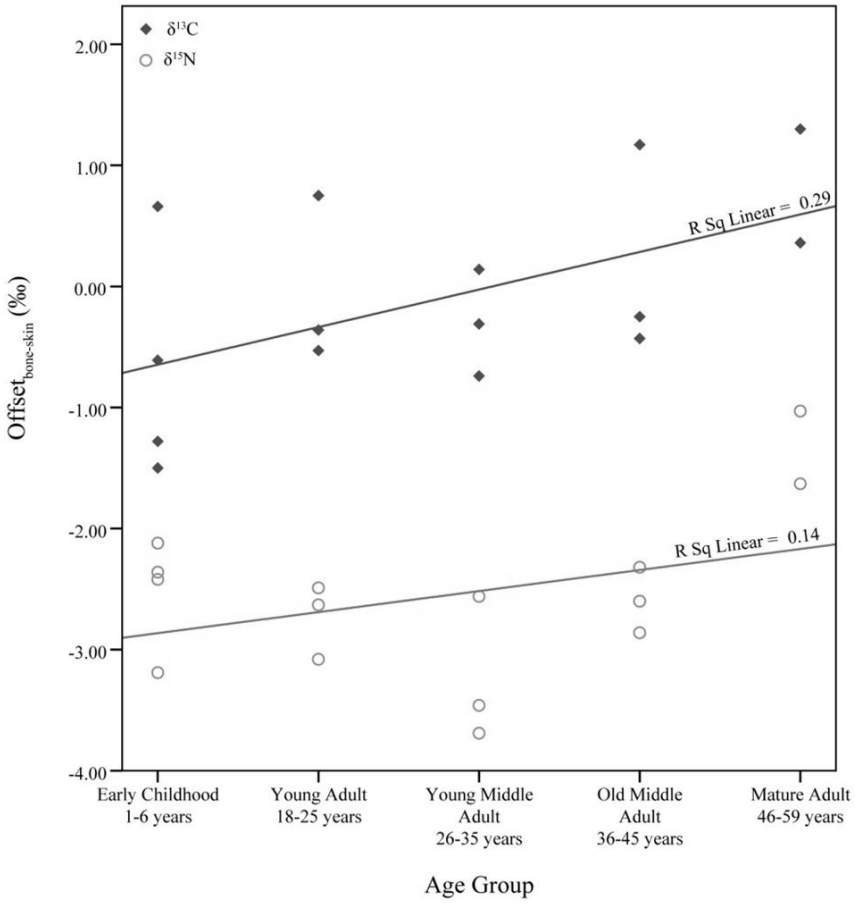

Figure 7.18 Correlation of age and bone-skin isotopic offset for both carbon and nitrogen values.

A Pearson's Correlation was carried out with the isotopic offset values of the 15 bone-skin pairs from the dataset that could be put into age categories (Figure 7.18). For nitrogen, the correlation was not statistically significant, $r = .37$, $p > .05$. This finding agrees with the majority of other findings that age does not correlate with isotope value. For carbon there is significant correlation ($r = .54$, $p < .05$). The reasons for this are unknown, but the variation is not large, with offsets ranging from a minimum of -1.5‰ to a maximum of 1.3‰.

Time of day of synthesis

A study by Simmons and Nichols (1966) suggested that bone metabolism in rats shows diurnal variation, with the process occurring at night. It is possible that collagen synthesis has similar diurnal variation. Thus, if skin collagen synthesis occurred in the inverse period to bone collagen formation it might be responsible for the observed offsets due to the different levels of nutrients in the body and thus isotopic value of the body pool.

However, in the study by Simmons and Nichols (1966) the rats were normally active at night which involved consumption of food which was provided *ad libitum* in the experiment. As such the model of the rats is not necessarily suitable for the argument made here as activity and feeding at night in humans would not be considered normal behaviour. Taking the hypothesis that bone is synthesised at one time of day only (day or night) and skin the other, physiological or biochemical mechanisms may be responsible for the offsets observed.

If one considers that during one half of the 24 hour period food is consumed and the individual is active (eating, excreting urea etc) and the other half the individual is inactive, then there will be clear differences in the levels of dietary constituents (protein, carbohydrates etc) available to the body at different times. These will in turn affect the way in which the body incorporates amino acids into collagen, with different levels of routing and *de novo* synthesis of amino acids (see Chapter 4), which has been shown to result in different bulk $\delta^{13}C$ values but has shown mixed results for $\delta^{15}N$ (Hare *et al.* 1991).

Recycling of urea has also been suggested as affecting $\delta^{15}N$ values of tissues. However, no consensus in the effects of stresses connected to urea recycling (such as water or protein) has been reached, with studies finding results which do not support each other. Additionally these studies have not investigated short time frame changes (Ambrose 2000; Sealy *et al.* 1987; Sponheimer *et al.* 2003a). The metabolic rate will also potentially play an important part in this scenario especially if there is a diurnal aspect to the tissue formation. This rate has been

shown to vary significantly within individuals of the same species even when factors such as weight, age, sex and physical activity are accounted for (Speakman *et al.* 2004).

There are many mechanism that may be involved in the processes that contribute to the offset seen between skin collagen and the other types of collagen analysed in this thesis. It is beyond the scope of this thesis to fully reconcile what is responsible for the observed offset, although it appears that it is likely to be multi-factorial. In the absence of a theoretically derived offset value, I shall use the values from the animal feeding study by O'Connell (unpublished) of $\delta^{13}C_{bone\text{-}skin}$ = -0.15 ±0.28‰ and $\delta^{15}N_{bone\text{-}skin}$ = -0.71 ±0.74‰ (n=15). Whilst these are animal data, it is from a controlled experiment and therefore eliminates any variation in the isotopic values that may have been derived from dietary choice or seasonal availability of food. It does come with the caveat of being derived from herbivores with different digestive physiologies, which will not have the complication of direct routing of indispensible amino acids or dispensible amino acids from protein sources such as meat. Therefore it may not prove to be the best comparison for human data. Dentine data are not available from O'Connell's study.

Taking the O'Connell (unpublished) data as the expected offset then, there is no significant difference between the Peruvian data and O'Connell in terms of $\delta^{13}C_{bone\text{-}skin}$ ($t(23.8)= 0.75$, $p>.05$) but there is for the $\delta^{15}N_{bone\text{-}skin}$ values ($t(32)= -7.6$, $p<.001$), as can be seen in the box plot of the values (Figure 7.19).

Some overlap is seen between the nitrogen isotopic values between the two data sets, with three individuals from the Peruvian dataset falling within the range of the O'Connell dataset (0.25‰ to -1.84‰). This suggests that 16 individuals are outliers in terms of their nitrogen isotope offset, regardless of time period, but none for carbon. This is supported using z-scores, which measure how many standard deviations the Peruvian values are away from the mean of O'Connell (unpublished). Using this method I have identified 16 outliers for nitrogen out of a total of 19 in the Peruvian material (Table 7.2).

Either there was a change in the nitrogen isotopic values of these individuals' lives near to the time of their death (whether by choice or through other means) or the value proposed as the expected offset is not accurate or appropriate as it was based on animals rather than humans. Analysis of the hair data will help to elucidate whether there was a change in diet during the final months of life compared to the lifetime average as this would be represented by an offset that also does not conform to the expected values derived from controlled studies.

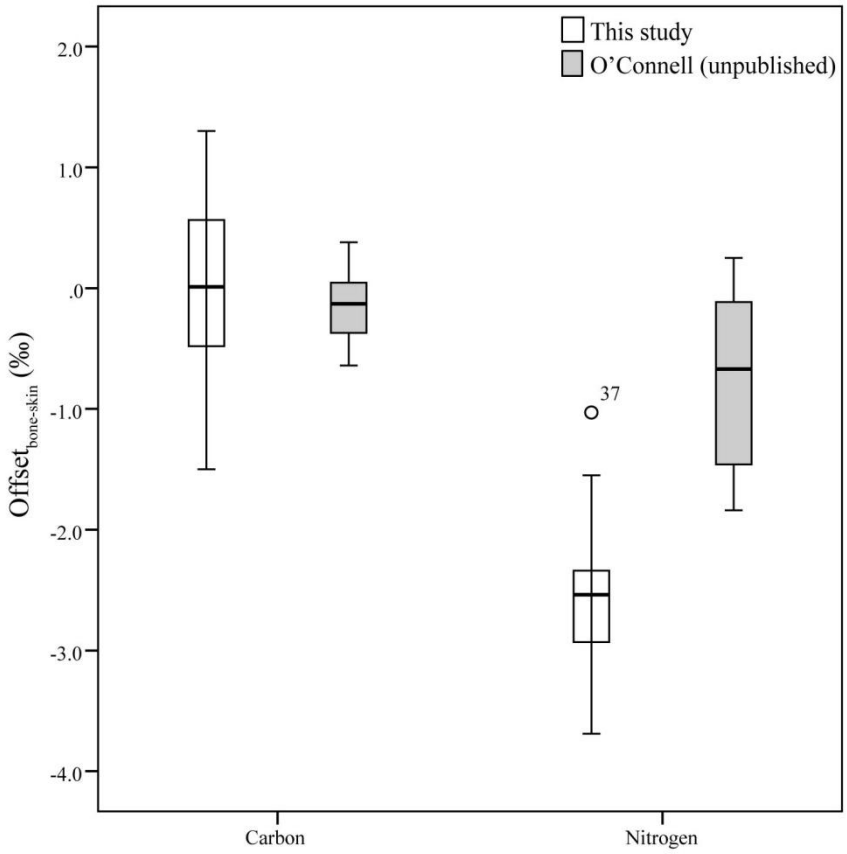

Figure 7.19 Comparison of the carbon and nitrogen isotopic bone skin offsets (n=19) from this study and O'Connell (unpublished data, n=15).

Table 7.2 Conversion of the bone-skin offset values from this thesis into z-scores based on the O'Connell (unpublished) data. My data that are within one standard deviation of the mean proposed by O'Connell should fall between -1.96 and 1.96. The further away from these values my data are, the further away from the O'Connell mean value. The expected percentage of population for each score is based on a Gaussian distribution.

Z-Score	**Expected % of population that should fall in score**	**Number of individuals from Peruvian dataset**		**% of total number of individuals**		**No. of individuals who fit z-score category for both C & N**
		$\delta^{13}C$	**$\delta^{15}N$**	**$\delta^{13}C$**	**$\delta^{15}N$**	
-1.96 to 1.96	95%	10	3	53%	16%	2 (11%)
<-1.96 and >1.96	5%	9	16	47%	84%	7 (37%)
<-2.58 and >2.58	1%	7	7	37%	37%	3 (16%)
<-3.29 and >3.29	0.1%	5	3	26%	16%	0

7.2.3 Collagen-Keratin Offset

Bone-hair pairs are available from 46 individuals. Mean values were used for those individuals whose hair was subject to segmented analysis (n=34). The mean bone $\delta^{13}C$ value for this subset is -12.5 ±2.4‰, with a range of -8.8‰ to -17.5‰. The mean bone $\delta^{15}N$ value is 9.8 ±0.9‰, with a range of 8.3‰ to 12.3‰. For hair the mean $\delta^{13}C$ value is -13.4 ±2.5‰ and the mean $\delta^{15}N$ value is 9.2 ±1.4‰. The ranges for hair are -9.1‰ to -17.7‰ and 6.9‰ to 13.4‰ for carbon and nitrogen respectively. The mean offset $\delta^{13}C_{bone\text{-}hair}$ value of 0.9 ±1.1‰ and for $\delta^{15}N_{bone\text{-}hair}$ = 0.5 ±1.2‰, with a range of -3.0‰ to 2.2‰ for carbon isotopes and -3.0‰ to 2.6‰ for nitrogen isotopes.

O'Connell *et al.* (2001) in a study on modern free-living individuals (n=8) found the bone-hair offset to be 1.4 ±0.5‰ for $\delta^{13}C$ and 0.9 ±0.2‰ for $\delta^{15}N$. These means are statistically different from the Peruvian hair-bone pairs. This is evident when the values are converted to z-scores based on the mean and standard deviation given by O'Connell *et al.* (2001). It is clear that the Peruvian data do not conform to the expected offset values, with only eight individuals (17%) falling into the z-scores for both carbon and nitrogen isotopes that would be expected to encompass 95% of the population (Table 7.3).

Table 7.3 Conversion of the bone-hair offset values from this thesis into z-scores based on the O'Connell et al. *(2001) data. My data that are within one standard deviation of the mean proposed by O'Connell* et al. *should fall between -1.96 and 1.96. The further away from these values thatmy data are, the further away from the O'Connell* et al. (2001) *mean value. The expected percentage of population for each score is based on a Gaussian distribution.*

Z-Score	Expected % of population that should fall in score	Number of individuals from Peruvian dataset		% of total number of individuals		Number of individuals who fit z-score category for both C & N
		$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	
-1.96 to 1.96	95%	28	14	61%	30%	8 (17%)
<-1.96 and >1.96	5%	18	32	39%	70%	12(26%)
<-2.58 and >2.58	1%	11	27	24%	59%	5 (11%)
<-3.29 and >3.29	0.1%	6	23	13%	28%	3 (7%)

This could be due to several factors: either the range from the modern dataset is inaccurate; the differences in bone sampled (femoral head by O'Connell *et al*. 2001 and skull by this study) and their turnover rates may result in a slightly different relationship with the hair; or there was a dietary change in the vast majority of the individuals from Peru. The turnover rates between femoral bone and skull both are both considered long term and in a middle aged adult represent between 30-50 years of life (Rummel *et al.* 2007), with a bias towards collagen synthesised in adolescence due to its faster turnover rate (Hedges *et al.* 2007). The dietary change would fit with the large amount of outliers seen in the skin data. However, it is first worth considering the validity of the data from O'Connell *et al.* (2001).

Firstly, the modern data are based on individuals consuming a C_3 based diet, whereas the individuals analysed here consumed a mixed C_3/C_4 or primarily C_4 based diet as suggested by their $\delta^{13}C$ values. Differing levels of C_3/C_4 dietary components have been shown to change the $\delta^{13}C$ value of tissues in a non-linear fashion (see Chapter 4) and therefore small changes in the components of a mixed diet may affect the offset values. In order to test this the data from O'Connell *et al.* (2001) were compared to the pairs that recorded a $\delta^{13}C$ values of -15‰ or less in bone or in hair. The ANOVA (carbon Welch's $F(3,23.8)= 5314$, $p<.001$; nitrogen $F(3,72)= 172.1$, $p<.001$) and post-hoc tests show that the modern data are different from the archaeological data regardless of whether the dataset is trimmed or not.

Taking a wider range of archaeological bone-hair offsets, in both a chronological and geographical sense, a similar scenario is seen (Table 7.4). Of 159 individuals from six studies (including this one) only 25, that is 16%, fall within the two standard deviation range of O'Connell *et al.*'s modern data.

One clear difference between the modern data and the archaeological data is the magnitude of the standard deviations associated with the mean values. The modern data have very small standard deviations (0.5‰ and 0.2‰ for carbon and nitrogen isotopes respectively), whereas the larger archaeological sample sizes see larger standard deviations (see Table 7.4). It therefore is reasonable to suggest that the modern human data are not fully representative of the variation naturally seen in a larger population.

Table 7.4 Mean isotopic bone-hair offset values from archaeological studies of human tissues where both tissues were available for each individual.

Reference	Location	Time Period	Total number of bone-hair pairs	Mean $\delta^{13}C$ offset ±1σ (‰)	Mean $\delta^{15}N$ offset ±1σ (‰)	Number that fall in modern range
Williams 2005	Coastal Peru	1476-1532 A.D.	53	1.9±1.4	0.5±1.3	8 (15%)
Shelnut 2006	Argentina	2120 B.C. - 1360 A.D.	5	1.9±1.1	0.0±1.0	2 (40%)
O'Connell & Hedges 1999	UK	1729-1859 A.D.	23	0.5±0.6	1.0±1.1	4 (17%)
Richards 2006	UK	19th Century A.D.	13	0.9±1.3	1.0±1.4	3 (23%)
Cadwallader unpublished	UK	1833-1853 A.D.	21	0.5 ±0.4	1.2 ±0.9	3 (14%)
This thesis	Peru	c.100 B.C. - 1400 A.D.	44	0.9±1.1	0.5±1.2	5 (11%)

In a much larger study incorporating bone-hair pairs from a variety of primates (n=83), including the data by O'Connell *et al.* (2001), Crowley *et al.* (2010) found much wider variation than O'Connell and colleagues (2001). The mean offsets of $\delta^{13}C_{bone\text{-}hair}$ value is 0.9 ±1.1‰ and for $\delta^{15}N_{bone\text{-}hair}$ = 0.8 ±0.9‰. There was no statistical difference between the values of species used, body size, phylogenetic relationship and as such this may prove to be a better comparison for the archaeological samples. Although the animals used in these data results did not have a controlled diet, their choice of what to consume was limited by the natural availability as well as their specialist diet. Therefore, the possibility of selective dietary change influencing the offset values should have been minimised.

Comparing my data from Peru to that from Crowley *et al.* (2010) there is no statistical difference between the mean offsets for both carbon and nitrogen. Again, using the trimmed dataset of values from my research the results remain the same (Kruskal-Wallis carbon $H(3)= 1.78$, $p>.5$; nitrogen $H(3)= 3.67$, $p>.05$), demonstrating that the presence of a C_4 isotopic signal in the Peruvian material does not have an effect on the offset. Likewise z-scores show a much better agreement between the expected percentage of population in each score group and the actual percentage using the Crowley *et al.* (2010) mean and standard deviation than the one proposed by O'Connell and colleagues (2001) (Table 7.5).

Table 7.5 Conversion of the bone-skin offset values from this thesis into z-scores based on the Crowley et al. *(2010) data. My data that are within one standard deviation of the mean proposed by Crowley* et al. (2010) *should fall between -1.96 and 1.96. The further away from these values my data are, the further away from the Crowley* et al. *mean value. The expected percentage of population for each score is based on a Gaussian distribution.*

Z-Score	**Expected % of population that should fall in score**	**Number of individuals from Peruvian dataset**		**% of total number of individuals**		**Number of individuals who fit z-score category for both C & N**
		$\delta^{13}C$	**$\delta^{15}N$**	**$\delta^{13}C$**	**$\delta^{15}N$**	
-1.96 to 1.96	95%	44	41	96%	89%	39 (85%)
<-1.96 and >1.96	5%	2	5	4%	11%	0
<-2.58 and >2.58	1%	1	3	2%	7%	0
<-3.29 and >3.29	0.1%	0	1	0%	0%	0

A similar pattern is repeated when the offsets from a number of other archaeological studies are considered (Table 7.6). This suggests that the issue is with the bone-hair offset proposed by O'Connell *et al.* (2001) rather than that the people in the lower Ica Valley dataset had undergone a dietary shift towards the end of their life. Additionally, these other archaeological datasets include populations who have had a mainly C_3 carbon isotopic input, like the original O'Connell *et al.* (2001) study, therefore supporting the observations seen in the trimmed dataset from this thesis discussed above.

Setting the significance level at 0.05 (or 5%) for the z-score values, there are seven outliers in the Peruvian dataset, although none when carbon and nitrogen isotopic offsets are considered in tandem. The two carbon outliers had $\delta^{13}C_{bone\text{-}hair}$ offset values of -1.5‰ and -2.2‰ and the five nitrogen outliers had $\delta^{15}N_{bone\text{-}hair}$ offset values of -3.0‰, -2.0‰, -1.9‰, -1.4‰ and 2.6‰. It is interesting to note that four of these outliers are negative and thus the isotopes were more positive in the keratin than in the collagen. As well as dietary change, physiological stress could have caused the observed offsets (Fuller *et al.* 2004; Fuller *et al.* 2005; Hobson *et al.* 1993; Mekota *et al.* 2006).

Table 7.6 The z-score values attained using other archaeological bone-hair offsets in comparison to the O'Connell et al. *(2001) data and Crowley* et al. *(2010) data. Archaeological data that are within one standard deviation of the mean proposed by the modern studies (O'Connell* et al. *2001 and Crowley* et al. *2010) should fall between -1.96 and 1.96. The further away from these values that the archaeological data are, the further away from the modern mean value. The expected percentage of population for each score is based on a Gaussian distribution.*

In comparison to O'Connell *et al.* (2001)						
		Percentage of individuals who fit z-score category for both C & N				
Z-Score	**Expected % of population that should fall in score**	**Williams 2005 n=53**	**Shelnut 2006 n=5**	**O'Connell & Hedges 1999 n=23**	**Richards 2006 n=13**	**Cadwallader unpublished n=21**
-1.96 to 1.96	95%	15%	40%	17%	23%	14%
<-1.96 and >1.96	5%	43%	60%	39%	23%	86%
<-2.58 and >2.58	1%	32%	40%	17%	15%	10%
<-3.29 and >3.29	0.1%	17%	0%	4%	8%	5%
In comparison to Crowley *et al.* (2010)						
-1.96 to 1.96	95%	68%	80%	91%	92%	100%
<-1.96 and >1.96	5%	6%	0%	0%	0%	0%
<-2.58 and >2.58	1%	4%	0%	0%	0%	0%
<-3.29 and >3.29	0.1%	0%	0%	0%	8%	0%

Only one controlled animal feeding experiment that has analysed paired bone and hair samples has been conducted. The carbon isotopic offset results are similar to Crowley *et al.*'s (2010) with a mean of 0.5 ±1.5‰ but the nitrogen isotopic offset is considerably different at -0.5 ±0.7‰ (O'Connell unpublished). This dataset is based on samples from four pigs and four goats and thus is limited by the small sample size in the same way as the modern human data. In z-scores the animal data perform extremely well for $\delta^{13}C$, with all Peruvian individuals falling with the range of values expected for 95% of the population. The nitrogen isotopic offset, conversely, performs considerably worse than Crowley *et al.* (2010), with thirteen outliers compared to just five.

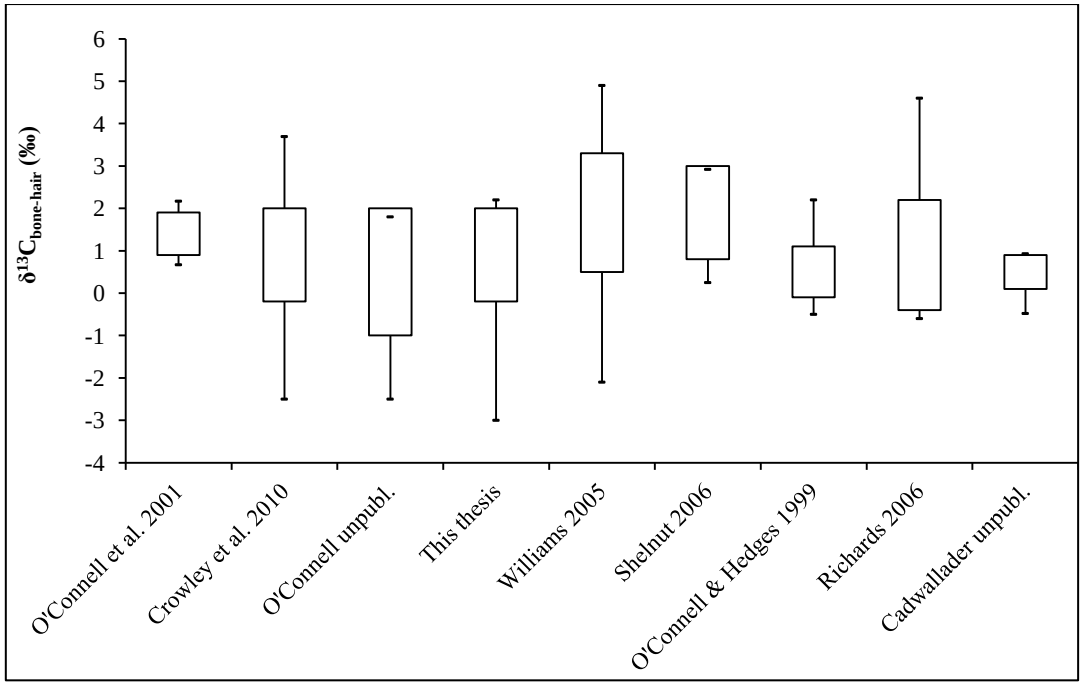

Figure 7.20 Ranges and standard deviations (1σ) of carbon isotope values for bone-hair paired data from archaeological and modern studies. All archaeological studies and O'Connell et al. *(2010) are based on human data. The Crowley* et al. *(2010) and O'Connell (unpublished) studies are based on animal data.*

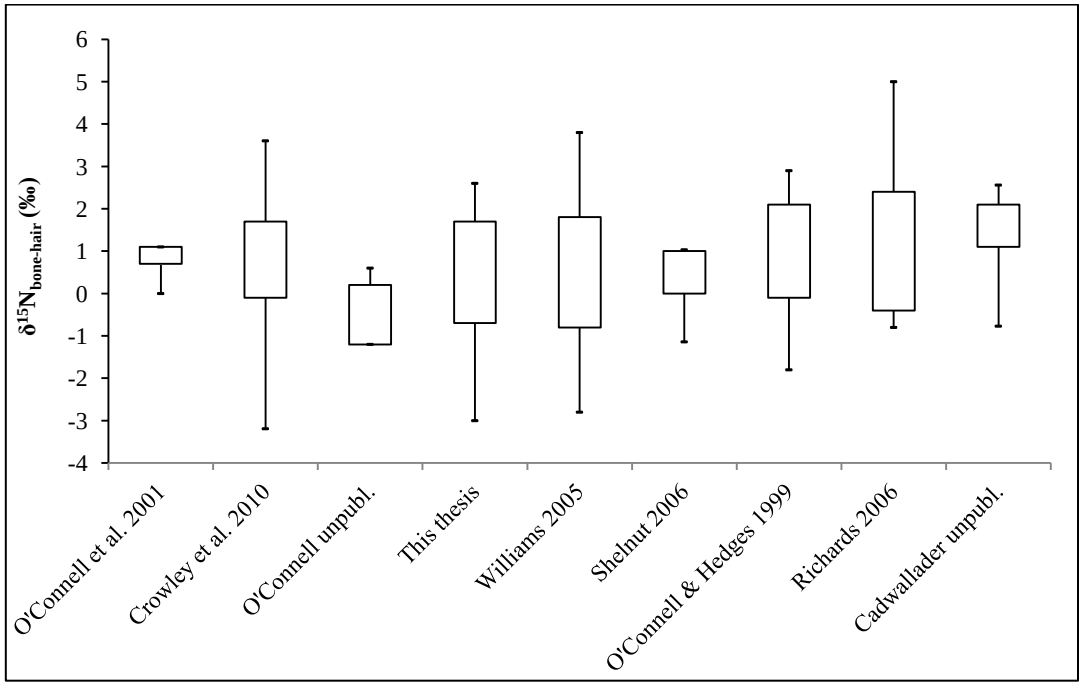

Figure 7.21 Ranges and standard deviations (1σ) of nitrogen isotope values for bone-hair pairs from archaeological and modern studies. All archaeological studies and O'Connell et al. *(2010) are based on human data. The Crowley* et al. *(2010) and O'Connell (unpublished) studies are based on animal data.*

I would suggest therefore that the O'Connell *et al.* (2001) values for bone-hair offset are not an accurate representation, nor are the animal data by O'Connell (unpublished) and that the wider study by Crowley *et al.* (2010) is more suitable to use when considering which individuals showed dietary variation between the times recorded in the two tissues (see Figures 7.20 and 7.21). By using a more conservative estimate such as Crowley *et al.*'s (2010), I will not be identifying outliers using a level of precision which is not supported in the wider literature. The outliers highlighted by comparison with the Crowley *et al.* (2010) data will be discussed in more detail in the discussions on the separate cemeteries.

7.2.4 Long-Term Diet Versus Diet Immediately Before Death

Theoretically the outliers in the bone-hair offset should be the same individuals as those in the bone-skin offset sample as both compare long term diet to before death diet. Eighteen individuals have all three tissues and therefore can be used to compare the two offsets. In order to accurately compare end of life diet using hair and skin, the two tissues must represent the same time period. Therefore the mean value of only the last three months of hair growth shall be used as skin has a turnover time of three months. Theoretically the identification of outliers should be identical for both offsets. Table 7.7 shows there is very poor agreement in the identification of outliers between the offsets for both carbon and nitrogen isotopes, as was also observed using the distribution plot method comparing the data. For carbon the individuals who were identified as an outlier in one offset were not identified as an outlier in the other. For nitrogen only three individuals are identified as outliers in both tissue pairings, whereas fifteen individuals are identified as an outlier in only one tissue offset. This discrepancy is probably due to the inaccuracy of the bone-skin offset as discussed earlier. This illustrates well how our knowledge of the relationship between how the tissues are formed and the dietary isotopes is lacking in detail. Clearly the theoretical understanding of how dietary isotopes are incorporated into the body tissues is not sufficient to be used to identify individual outliers as there is little agreement in the results from this population.

Table 7.7 Agreement of outliers identified in bone-skin (b-s) and bone-hair (b-h) offset for carbon and nitrogen isotopes. Outliers are marked with an 'x' and theoretically there should be agreement between the two offsets within each isotope, i.e. an x in both, or neither, columns for each isotope separately.

	Carbon		Nitrogen	
Individual	**b-s**	**b-h**	**b-s**	**b-h**
25	x		x	
26	x			
27	x		x	x
89	x			
20			x	
21		x	x	
22	x		x	
81	x		x	x
28			x	
36	x		x	x
37				x
39			x	
40	x		x	
41			x	
42	x		x	
47			x	
75			x	
76			x	

7.2.5 Hair -Skin Offset

From the Peruvian data (n=18) the offset between skin and hair from paired data is normally distributed for carbon but not for nitrogen isotope values. The mean $\delta^{13}C_{skin\text{-}hair}$ = 1.1 ±1.4‰ with a range of -1.2‰ to 2.8‰. The median value for the carbon offset is 1.5‰ and an IQR of -0.6‰ to 2.3‰. For $\delta^{15}N$ the mean offset value is 3.3 ±1.3‰ with a median of 3.4‰ and an IQR from 3.0‰ to 3.8‰. The range for the nitrogen isotope offsets is -1.0‰ to 5.1‰.

Theoretically the ranges of observed offsets for paired hair and skin results should be narrow as they both represent similar time periods yet this is not the case for these data. If instead of using a mean value for the hair from all segmented values the mean of only the last 3 months is used, i.e. the same period represented by the skin, the results change to a mean $\delta^{13}C_{skin\text{-}hair}$ of 0.8 ±1.6‰ with a range of -2.1‰ to 2.8‰. The median value for the carbon isotopic offset is 1.0‰ with an IQR of -0.9‰ to 2.3‰. For the nitrogen isotopic offset the mean value is 3.0 ±1.5‰ with a median of 3.3‰ and an IQR of 2.3‰ to 3.8‰. The range for the $\delta^{15}N$ offsets

is -1.8‰ to 4.7‰. When attempting to control for the chronological variation in the hair samples, then, the opposite of what would be expected with the ranges has happened (Figure 7.22). A wider range of offsets suggests that there is a discrepancy between the time period represented by the tissues or that certain parts of the diet are routed preferentially into the tissues differently. This supports what was observed in the distribution curves with disagreement between the two tissues.

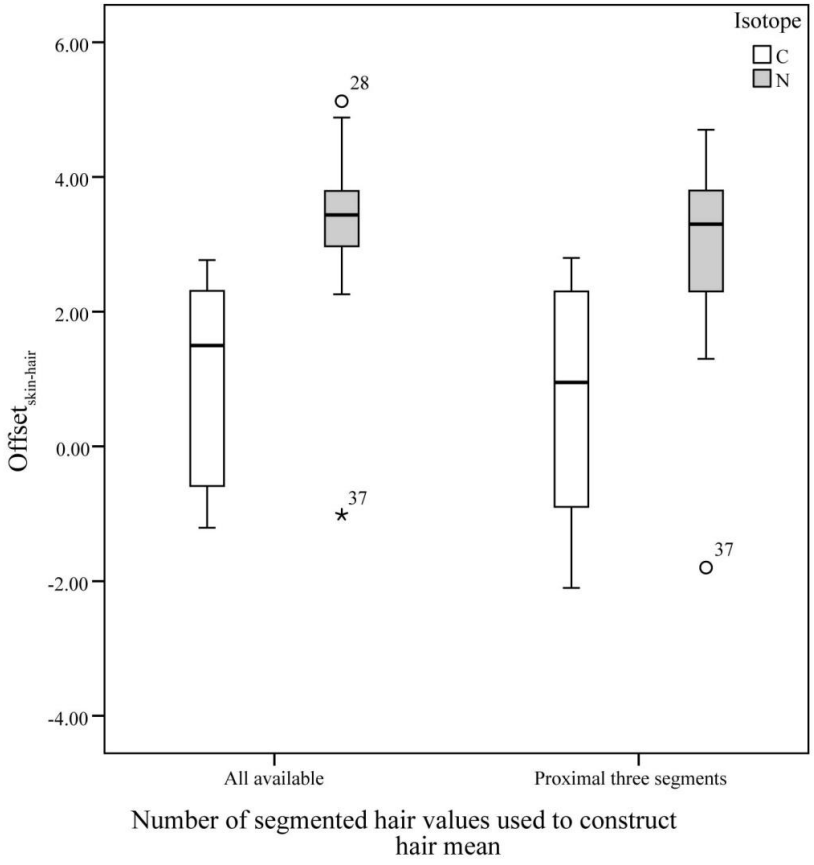

Figure 7.22 Comparison of the skin-hair offsets (n=18) for both carbon and nitrogen isotopes using all available hairs segments versus only the last three proximal segments of hair. The proximal three hair segments should represent the same formation time as the skin, and thus have a narrower range of offset values but the opposite is seen here.

This may in part be due to the growth cycle error in hair, where both anagen and telogen hairs are analysed together yet are not synchronous in regards to time of formation. This has been shown to significantly affect the isotopic values of individuals who were physiologically

stressed with a lag in the segmented samples of hair of up to 3.5‰ for $\delta^{15}N$ and 1.1‰ for $\delta^{13}C$ (Williams *et al.* 2011). For non stressed individuals the difference in using only anagen hairs compared to mixed phase hairs is much smaller, $\delta^{13}C = 0.2 \pm 0.3‰$ and $\delta^{15}N = 0.5 \pm 0.5‰$ (Williams *et al.* 2011). Pathology indicative of physiological stress was noted for only one individual in this sub-sample - a juvenile with signs of cribra orbitalia. The three other juveniles in this group may also have been physiologically stressed at the time of death given that they did not reach adulthood. Removing these four individuals does not alter the range of offset values and is likely to be a false economy as acute illness or diseases which may lead to physiological stress and death will not result in skeletal manifestations in children and adults alike.

Accepting the values as they are, regardless of the reasons, their comparison with the expected offset may highlight any outliers, which may be those with an abnormal amount of telogen hairs.

Only one controlled feeding study using pigs and goats (n=8) has compared the isotopic values of skin and hair. The isotopic offset between skin and hair in this experiment was 1.3 ± 0.5‰ for carbon and 0.4 ±0.2‰ for nitrogen (O'Connell unpublished). A theoretical offset can also be derived from the data published on the two tissues in relation to other tissues. As the enrichment between the tissues follows from the most positive skin>bone>hair, the hair to skin enrichment can be derived from each tissues' enrichment to or from bone. The mean for skin-hair values is achieved through addition of the two means:

$$\text{mean } \delta^{13}C_{\text{skin-hair}} = \text{mean } \delta^{13}C_{\text{bone-hair}} + \text{mean } \delta^{13}C_{\text{bone-skin}}$$

and the error on this mean is worked out through error propagation:

$$\text{error } \delta^{13}C_{\text{skin-hair}} = \sqrt{(\text{stdev of } \delta^{13}C_{\text{bone-hair}} + \text{stdev of } \delta^{13}C_{\text{bone-skin}})}.$$

The standard deviations are used for error propagation as they will give a more conservative (i.e. higher) error value. Given the multiple variable factors of the data (in addition to measurement error) it is important not to produce an error on the compound mean that inaccurately reflects the precision of the measurement. Taking Crowley *et al.* (2010) as the most reliable hair to bone enrichment and O'Connell (unpublished) as the bone to skin enrichment, the values for hair to skin enrichment are $\delta^{13}C = 1.1 \pm 1.1‰$ and $\delta^{15}N = 1.5 \pm 1.1‰$. This carbon isotopic offset value is close to that observed by O'Connell (unpublished) of 1.3 ±0.5‰ but the derived nitrogen isotopic offset value of 1.5 ±1.1‰ is

much larger than the one observed by O'Connell (unpublished) in the animal data (0.4 ±0.2‰). This discrepancy has already been observed in the O'Connell (unpublished) data for the bone-hair offset, when it was compared to data from archaeological human populations and the primate data by Crowley *et al.* (2010).

Z-scores have been used to compare the Peruvian data, using only the proximal three months of hair, with the offset values (mean and one standard deviation) observed by O'Connell (unpublished). Setting the significance level at 0.05, these show very poor agreement in the case of $\delta^{15}N$ and moderate agreement for $\delta^{13}C$ (Table 7.8).

Table 7.8 Agreement of the skin-hair isotopic offsets from the thesis when converted to that proposed by O'Connell (unpublished) based on animal data. My data that are within one standard deviation of the mean proposed by O'Connell (unpublished) should fall between -1.96 and 1.96. The further away from these values my data are, the further away from the O'Connell (unpublished) mean value. The expected percentage of population for each score is based on a Gaussian distribution.

Z-Score	**Expected % of population that should fall in score**	**Number of individuals from Peruvian dataset**		**% of total number of individuals**		**Number of individuals who fit z-score category for both C & N**
		$\delta^{13}C$	**$\delta^{15}N$**	**$\delta^{13}C$**	**$\delta^{15}N$**	
-1.96 to 1.96	95%	8	0	44%	0%	0 (0%)
<-1.96 and >1.96	5%	10	18	66%	100%	10 (66%)
<-2.58 and >2.58	1%	6	18	33%	100%	6 (33%)
<-3.29 and >3.29	0.1%	5	18	28%	100%	28 (5%)

Using the derived values much better agreement is seen in both carbon and nitrogen isotopes for the z-scores but this is still lower than expected (Table 7.9). The level of agreement with the expected value is not high. This is another example of where the understanding of how dietary isotopes are used by the body is not fully understood and data from controlled animal feeding experiments may not be a good model for humans. The reason why the Peruvian data do not fit the pattern well is mostly like due to the problems encountered with the bone-skin data.

Table 7.9 Agreement of the isotopic values for the skin-hair offset from this thesis when converted to the value derived from published sources of data. My data that are within one standard deviation of the derived mean should fall between -1.96 and 1.96. The further away from these values my data are, the further away from the derived mean value. The expected percentage of population for each score is based on a Gaussian distribution.

Z-Score	Expected % of population that should fall in score	Number of individuals from Peruvian dataset		% of total number of individuals		Number of individuals who fit z-score category for both C & N
		$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$	
-1.96 to 1.96	95%	14	11	78%	61%	8 (44%)
<-1.96 and >1.96	5%	4	7	22%	39%	1 (6%)
<-2.58 and >2.58	1%	2	4	11%	22%	0 (0%)
<-3.29 and >3.29	0.1%	0	0	0%	0%	0 (0%)

7.3 Conclusions

For this study, examining life histories at the level of the whole population has been much more successful than at the individual level. Too little is currently known about the synthesis of the body tissues to be able to identify outliers based on the comparison of the isotopic values of two tissues. The offsets that have been proposed for the different tissues in humans are not well constrained, often being too narrow and unrepresentative of the full variation of a population.

The technique also is not sensitive to the subtler trends seen, such as the broadening of diets between life phases or the shift to more positive or negative results. Whilst the whole population distributions are not always in complete agreement with the paired tissue distributions, on the whole it is possible to identify trends in the diet between the four tissues. The small sample sizes for the Early Horizon and Early Intermediate Period have limited the degree to which any trends can be confidently identified. The most significant trend is in the Middle Horizon data, with the broadening of diet from infancy into adulthood The data show a bimodal carbon distribution for three tissue types (bone, hair and tooth), suggesting the presence of different dietary regimes. However, this bimodality is most strongly present in the tissues representing the childhood diet, with this division between the two dietary strategies weakening in adulthood, caused by a broadening of the range of dietary inputs. The

Late Intermediate Period data are constant over the lifetime of the population in terms of the breadth of the isotopic inputs. This suggests that the dietary inputs were stable in terms of isotopic composition.

Chapter 8 Archaeological Results and Discussion

In Chapter 6 it was observed that over the four time periods, the carbon isotopic values became increasingly positive, whilst the nitrogen values remained similar. This chapter will present and discuss all the isotopic results by time period in context of the archaeology of the lower Ica Valley. For each time period, the analysis starts with the faunal results and then moves on to the human data as the former are essential for interpreting the latter. The human data are first examined for a general dietary overview. Analysis and interpretations are then given for seasonal diets, pathological and dietary relationships and finally dietary life histories. Chapter 9 will then explore how these observations and interpretations fit into the current understanding of south coast archaeology.

The basis for accepting the results of the collagen and keratin samples is the same as that detailed in the beginning of Chapter 6.Statistical tests were conducted using SPSS version 20.x and PAST version 2.16 (Hammer *et al.* 2001) for multivariate and cluster analysis. Where principal component analysis is used, all possible variables for which there is data applicable to the tissue shall be used, e.g. $\delta^{13}C$ value, $\delta^{15}N$ value, cemetery, age, sex, hair length, tooth type etc.

8.1 Archaeological Plants

The twenty-eight archaeological plant samples, detailed in Section 5.4, were submitted for carbon isotope analysis in order to give an indication of the carbon ranges of the plants in the pre-Columbian era. The 22 archaeological plants that produced good quality results fell into the range of -27.0‰ to -10.3‰ for $\delta^{13}C$. The mean value was -19.7 ±5.9‰. There is a clear bimodal distribution due to the presence of both C_3 and C_4 plants (Figure 8.1).

The mean $\delta^{13}C$ value for the C_3 plants (n=15) is -23.6 ±1.3‰, with a range of -27.0‰ to -22.0‰. For the C_4 plants (n=7) the mean value was -11.6 ±1.2‰, with a range of -13.7‰ to -10.3‰. Both groups are normally distributed (Kolmogorov-Smirnov test, $p>.05$). The plants included in this study include both domesticated and wild species, such as maize, *huaranga*, manioc, beans and various fruits.

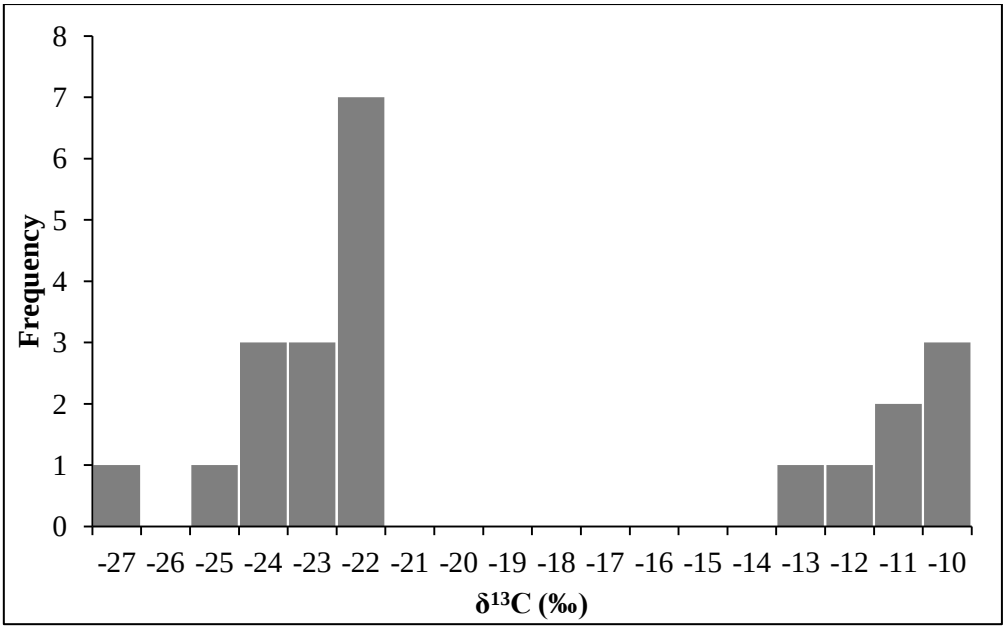

Figure 8.1 Distribution of carbon isotope values from archaeological plants analysed for this thesis.

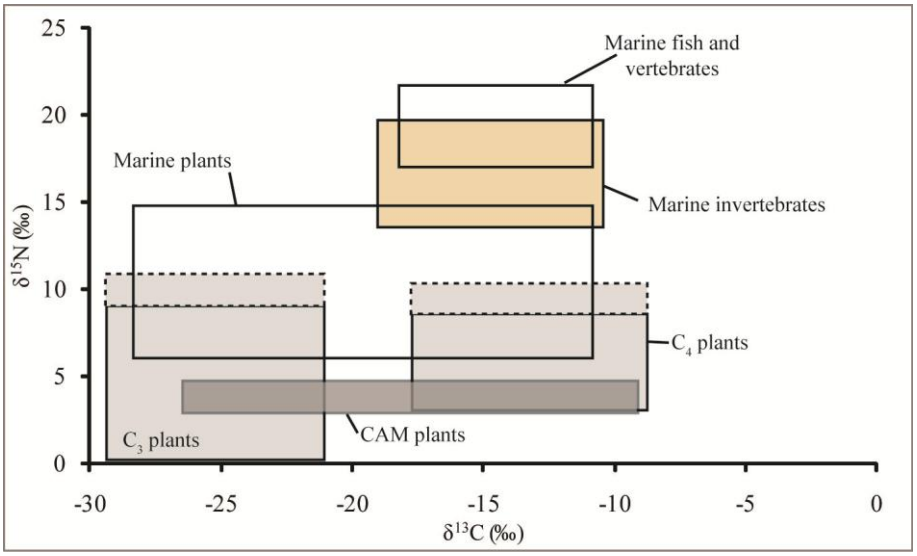

Figure 8.2 Graph of the isotopic background signature of plant and marine resources based on archaeological and modern data. Archaeological data are taken from this thesis, modern data are taken from Cadwallader et al. *(2012), DeNiro & Hastorf (1985) and Tieszen & Chapman (1992). Modern data have been corrected for the Suess effect using the formula proposed by Long* et al. *(2005). The dashed boxes on top of the C_3 and C_4 plant represent the elevated nitrogen values expected for water stressed plants.*

Two Cyperaceae specimens were C_4, which is interesting as both of these families contain edible wild plants that could have contributed to the diet. Wild foods as a dietary source, especially those that are C_4 have often been overlooked in isotopic studies in the past in favour of maize as the source of the C_4 signal (Cadwallader *et al.* 2012). Using these data as well as published sources the isotopic signals of the plants that may have been part of the pre-Columbian food chain on the south coast can be summarised as shown in Figure 8.2.

8.2 Early Horizon

8.2.1 Faunal Data

Bone samples were run for 15 separate animals, 11 of which were identified as camelid. The remaining four were birds (n=3) and a single rat. One wool and one tooth sample from camelids were also run. There are no paired tissues samples from this period. The animals are broken down into the three cemeteries as detailed in Table 8.1. All samples had acceptable C:N ratios and all bone and tooth collagen samples had acceptable yields and percentages of carbon and nitrogen (see Appendix 5).

Table 8.1 Faunal samples analysed from the Early Horizon cemeteries.

Cemetery	Sample No.	Species	Tissue Type	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
1001	AN1	Camelid	Bone	-15.3	6.9
1001	AN10	Camelid	Bone	-12.6	6.2
1001	AN3	Camelid	Wool	-14.2	6.1
1002	AN40	Camelid	Bone	-15.7	5.6
1002	AN41	Camelid	Bone	-16.8	9.6
1002	AN42	Camelid	Bone	-10.7	7.2
1004	AN4	Camelid	Bone	-13.8	7.3
1004	AN5	Camelid	Bone	-18.8	10.3
1004	AN6	Camelid	Bone	-11.8	8.4
1004	AN7	Camelid	Bone	-16.7	4.0
1004	AN8	Camelid	Bone	-17.1	6.7
1004	AN9	Camelid	Bone	-15.2	7.3
1004	AN11	Bird unidentified	Bone	-12.7	17.6
1004	AN12	*Sula variegata* (Peruvian booby)	Bone	-11.3	15.8
1004	AN13	*Sigmodon* sp. (Cotton rat)	Bone	-15.0	11.0
1004	AN15	Sulidae family (Gannet and booby family)	Bone	-11.6	15.4
1004	AN16	Camelid	Tooth	-17.0	8.2

The mean value for the bird samples (n=3) is -11.8 ±0.7‰ for $\delta^{13}C$ and 16.3 ±1.2‰ for $\delta^{15}N$. From these values it is clear that the birds all consumed a marine diet, especially when compared to the modern fish isotope values from the Pacific on the coast of northern Chile (Tieszen and Chapman 1992). This is also supported by the identifications made (C. Stimpson *pers. comm.*).

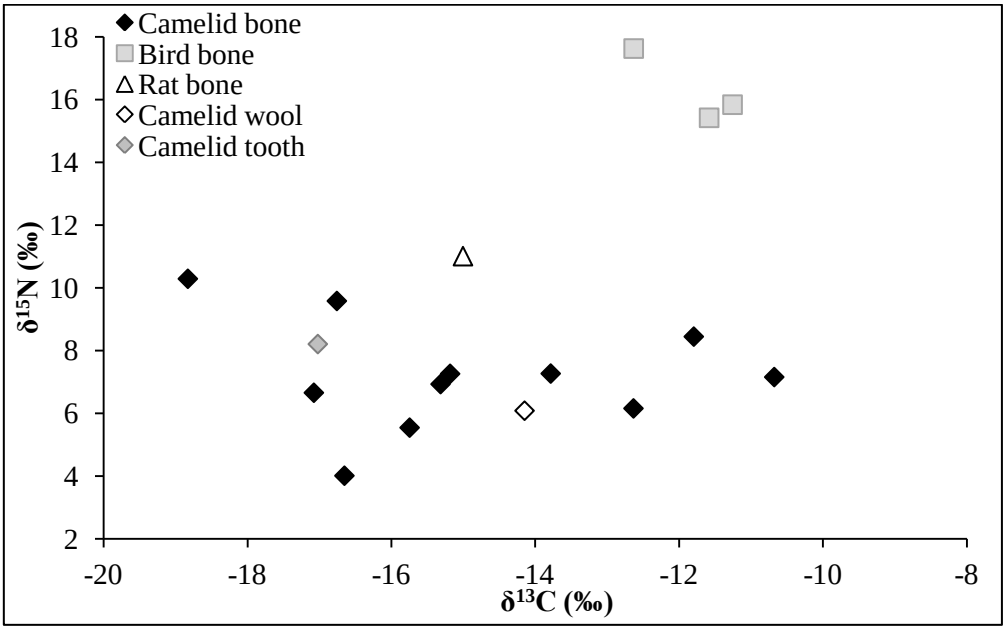

Figure 8.3 Isotopic results of faunal remains from the Early Horizon cemeteries.

The camelid bone data are normally distributed. The mean $\delta^{13}C$ for all the samples is -14.9 ±2.5‰ with a range of -18.8‰ to -10.8‰. For $\delta^{15}N$ the mean value is 7.2 ±1.8‰ with a range of 4.0‰ to 10.3‰. There is no significant difference between the camelids from three cemeteries for either carbon or nitrogen isotope values (Kruskal-Wallis $\delta^{13}C$ $H(2)= 0.68$, $p>.5$ and $\delta^{15}N$ $H(2)= 0.97$, $p>.5$). Both the wool and the tooth value fall within the ranges of the bone data (Figure 8.3).

The cotton rat $\delta^{13}C$ value (-15.0‰) suggests that this animal consumed a mixed C_3/C_4 based diet. The $\delta^{15}N$ value (11.0‰) is high in comparison to the camelids, yet the cotton rat is typically a herbivore and can live in a variety of habitats where grass and shrub are available (Voss 1992). There are three potential reasons for this elevated value: 1) the animal was actually carnivorous; 2) the animal consumed water stressed plants; 3) the sample dates from

a more recent time and the mean nitrogen value of the plants in the region has increased due to increased aridity.

Given the environment of the lower Ica Valley and the presence of camelids with high $\delta^{15}N$, the consumption of water stressed plants by some animals is very plausible. Plants grown on the floodplain of the Río Ica would not show the elevated $\delta^{15}N$ values due to the replenishment of the soil nutrients on an annual basis. However, plants growing away from the river, notably on the *lomas*, are likely to have been water stressed and have higher $\delta^{15}N$ values (e.g. Thornton *et al.* 2011). The rat therefore may have inhabited areas away from the floodplain of the river that could still support vegetation and thus consumed water stressed plants. Given that the lowest $\delta^{15}N$ value recorded for *lomas* plants by Thornton *et al.* (2011) was 6.3‰, camelids with value upwards of 9‰, i.e. 3‰ greater than the *lomas* value and outside the top value of the camelid mean plus one standard deviation, may have inhabited the *lomas*. Two samples fall within this range and thus are hypothesised to be either guanaco or domesticated camelids taken to the *lomas* to be foddered. The latter explanation if employed as a herd management strategy should apply to a large number of animals, i.e. the majority or whole of the herd. However, given that this is only two camelids out of eleven, the former explanation is more parsimonious.

8.2.2 Human Data

All four types of tissues were sampled from Early Horizon individuals. A total of 30 bone samples were run, 23 of which produced good quality collagen. Four of the failed samples did not yield any collagen and the remaining three had an unacceptable C:N ratio. Seven tooth samples were analysed and six produced good collagen. One tooth sample was not analysed as it was a deciduous tooth. Five hair samples were bulk sampled, three of which provided useable data. A further three individuals had hair samples that were cut into sections of varying lengths (10cm, 14cm and 17cm). One failed completely due to a poor C:N ratio. All the sections of one sample produced good results and the remaining sample is partly useable - out of 17 sections, only the fifth to the eleventh produced useable results. Only one skin sample was analysed from this period, which is of good quality. Table 8.2 details how the useable data break down by cemetery (see Appendices 3 and 4 for full results).

Table 8.2 Human samples from the Early Horizon that produced useable results broken down by cemetery.

Cemetery	Total no. of individuals	No. of bone samples	No. of tooth samples	No. of hair samples	No. of skin samples
1001	6	6	2	2	0
1002	6	6	1	0	1
1004	11	11	3	3	0

Seven individuals had more than one tissue type taken - three individuals had two tissues taken, and four individuals had three tissues sampled.

Overall Population Diet

Bone

The mean $\delta^{13}C$ values for each cemetery are -16.9 ±0.5‰, -15.5 ±1.6‰ and -15.7 ±1.0‰ for 1001, 1002 and 1004 respectively. The range in values for 1001 is approximately half the size of the other two cemeteries (1.5‰, 3.9‰ and 3.3‰ for 1001, 1002 and 1004 respectively). The mean $\delta^{15}N$ values are 11.1 ±1.5‰, 9.1 ±1.4‰ and 9.5 ±1.5‰ for the three cemeteries respectively. The ranges are 3.7‰, 3.8‰ and 5.4‰ for 1001, 1002 and 1004 respectively. Divided by cemetery the bone samples from 1001 and 1004 are significantly different from each other for carbon isotopes, although the sample sizes are small ($H(2)= 7.33$, $p<.05$, post hoc Kolmogorov-Smirnov $Z= 1.46$, $p<.05$). None of the cemeteries is significantly different for nitrogen isotope values (Figure 8.4). There are insufficient samples to compare the carbon and nitrogen isotopic values by age or sex.

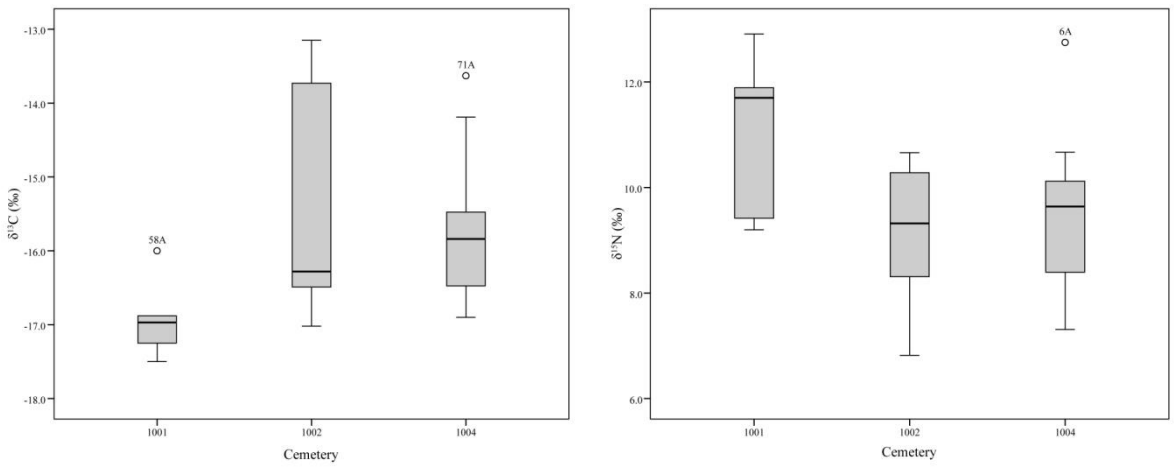

Figure 8.4 Carbon (left) and nitrogen (right) isotopic values from human bone samples from each Early Horizon cemetery.

Tooth

The mean tooth $\delta^{13}C$ value for all of the samples (n=6) analysed is -16.0 ±0.8‰ and the mean $\delta^{15}N$ value is 10.5 ±1.0‰. The range of values is -16.6‰ to -14.7‰ for $\delta^{13}C$ and 8.7‰ to 11.8‰ for$\delta^{15}N$. The small number of samples taken does not permit analysis by cemetery, sex, age or tooth type.

Hair

Once again the number of hair samples restricts the statistical analyses possible. The mean value of the five samples is -17.1 ±0.7‰ for carbon and 9.7 ±1.0‰ for nitrogen isotopic values. The $\delta^{13}C$ range is small, between -17.7‰ and -16.2‰, whereas the $\delta^{15}N$ range is closer to what would be expected based on the other tissues, 8.8‰ to 11.0‰. The values for both carbon and nitrogen isotopes are slightly more negative than seen for bone and tooth samples as is expected for keratin values. The variance along the segmented hairs will be discussed separately below.

Skin

The skin data, from cemetery 1002, have values of -13.7‰ and 12.2‰ for carbon and nitrogen isotope values respectively. These values are enriched in comparison to the other tissues analysed from this individual and the majority of the population.

From the graph (Figure 8.5) it is clear that the bone data encompass nearly all of the other tissue values. There is a wide spread for the carbon isotopes over approximately 5‰, suggesting both C_3 and C_4 inputs to the diet. Given the almost identical spread in carbon isotopes for the camelid values it is impossible to say whether the carbon isotopic signature of the humans was attained directly or indirectly. The nitrogen isotope values also show a wide spread of approximately 6‰ implying a varying level of meat consumption in the population. All individuals to some extent are enriched in $\delta^{15}N$ relative to the camelids, although the wide range in camelid values makes it difficult to assess the trophic level of the lowest $\delta^{15}N$ human individuals. Those individuals with the highest $\delta^{15}N$ could also be simply explained as consuming terrestrial meat, although it is possible that there was also some aquatic input into the diet either from freshwater or marine resources. Those individuals with the lowest $\delta^{15}N$ values may have consumed a higher proportion of legumes, which have a

$\delta^{15}N$ value close to 0‰, than the rest of the population. The remains from the leguminous huarango tree (*Prosopis* sp.) have been recovered in fairly large quantities from the Samaca and Ulluajaya basins from both the Early Ocucaje and Early Nasca - the two time periods that fall either side of the population studied here (Beresford-Jones *et al.* 2011b). These have already been proposed as being important wild food resources in the Early Horizon, due to their high sugar content. Due to the high protein content in legumes, this could have contributed to human $\delta^{15}N$ signals more than other plants, causing a more negative value than would otherwise be expected from an individual consuming terrestrial resources, thus supporting the argument made about the importance of this resource based on the archaeobotanical data (Beresford-Jones *et al.* 2011b).

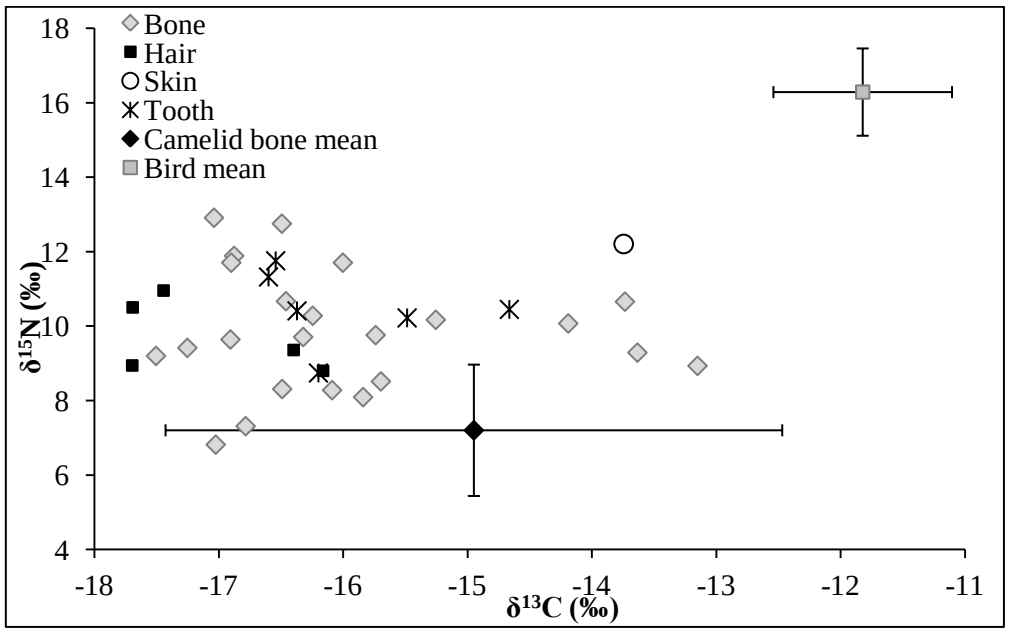

Figure 8.5 Isotopic results from all human tissue samples and faunal bone samples from the Early Horizon cemeteries. Error bars represent one standard deviation, centred around the mean value for the faunal samples.

Examining just the bone data from the three cemeteries (Figure 8.6), it is clear that Cemeteries 1002 and 1004 are similar in terms of isotopic ranges, whereas 1001 is much more restricted. It is unknown whether this is a real difference or an artefact of sample size. What is interesting is the hint of a bimodal carbon isotope distribution, with four individuals having more enriched carbon isotope values than the rest and a seeming gulf of data between

-15‰ and -14‰. This would suggest a separation in dietary components in terms of the carbon isotopes of the dietary inputs, which may translate into different preferred plant foods or different fodder bases for a terrestrial meat source. This latter reason may thus suggest different herd management or hunting strategies. However, given such a small sample it is difficult to lend weight to the presence of two dietary groups and thus the hypothesis remains speculative.

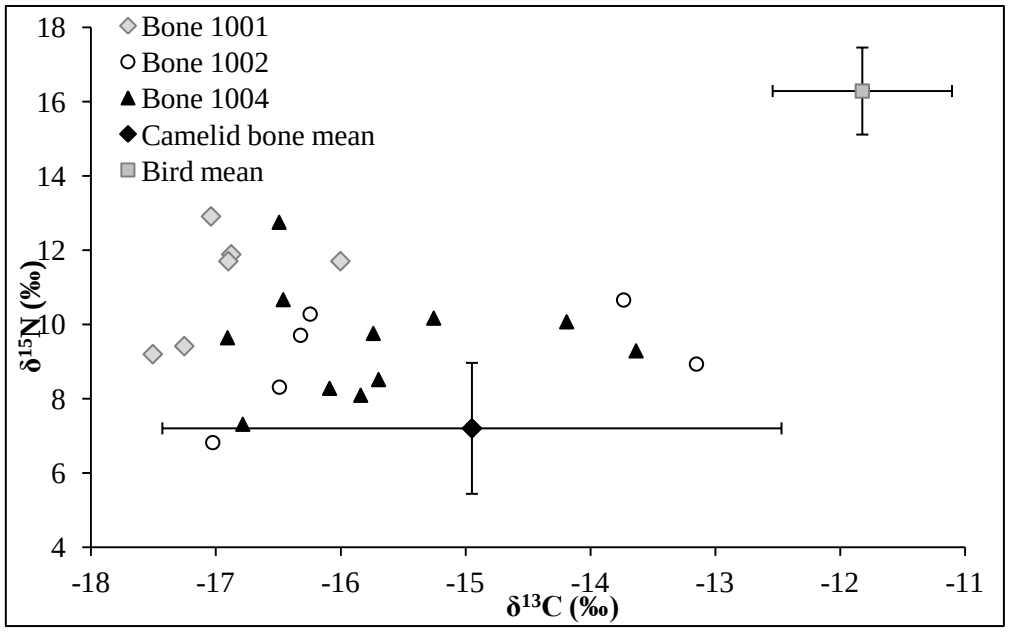

Figure 8.6 Human bone data by cemetery along with the faunal mean isotopic values. Error bars represent one standard deviation, centred around the mean values for the faunal samples.

Seasonal Diet

Segmented hair data are available for only two individuals. Individual 69 has a range of 1.6‰ along the hair length (10 segments) for both carbon and nitrogen isotopes. Individual 67 has a range in $\delta^{13}C$ values of 1.9‰ and a range of 2.3‰ in $\delta^{15}N$ values across seven segments of hair.

Following Webb *et al.* (2011a), variation in an individual's carbon isotope results greater than 2.5‰ is an indicator of the exploitation of multiple production zones. I would also argue that variation to this degree could indicate a highly seasonally determined exploitation of resources *within* the local area as both C_3 and C_4 resources are available. Below 2.5‰, the

variation caused by resources switches cannot be separated from natural variation in the isotopic signature of the background ecology. Similarly from the range of camelid values, it is clear that there is also considerable variation in the nitrogen isotopic values of the background ecology. In order to argue that the variation was due to movement or a strong seasonal exploitation, I would expect the variation along the hair length to be in the region of 3‰ or higher so that a trophic level change is clearly evident. Both individuals show low amounts of variation in carbon and the nitrogen isotopes, with all values falling within the range encompassed by the whole population data. Therefore these individuals were not consuming a highly seasonal diet nor were they exploiting multiple zones or resource areas.

Osteology and Pathology

A small number of individuals presented pathological conditions and in some case multiple pathologies. The pathologies were those concerned mainly with aging, i.e. joint disease and dental pathologies. There is no clear relationship between isotopic value and presence of pathology, including two cases of cranial deformation (Figure 8.7).

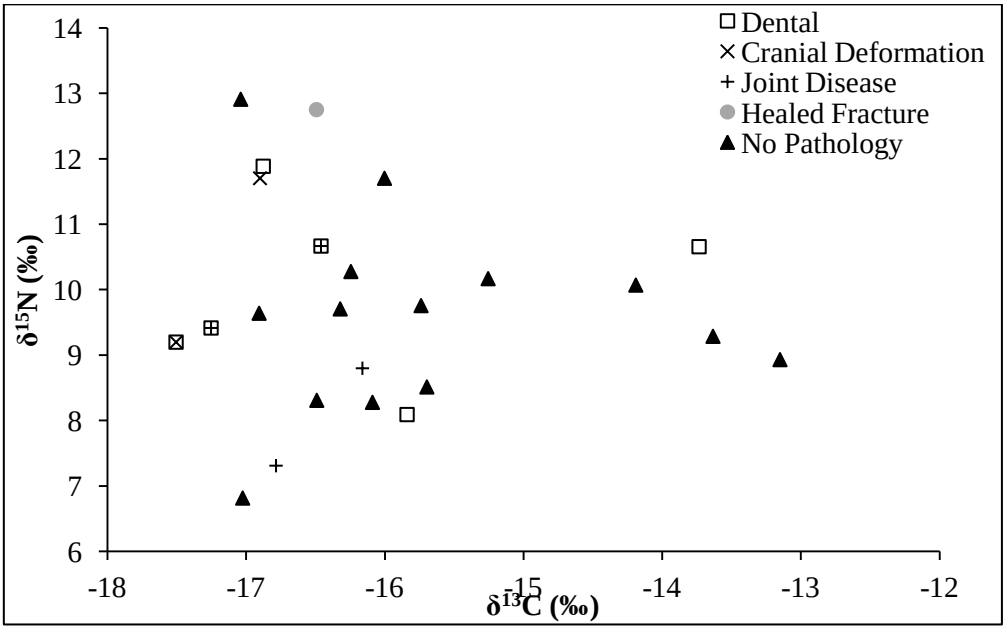

Figure 8.7 Isotopic results of the human bone samples from the Early Horizon cemeteries plotted by the type(s) of pathology observed on the skeletal remains. Those individuals with more than one pathology observed are represented by multiple symbols overlaid together.

Life Histories

Seven adult individuals can be investigated with respect to life histories and the way their isotopic signatures vary in the tissues analysed. All of the isotopic changes observed in the tissues are of a fairly small magnitude (Figure 8.8). For example, the differences between the tooth, bone and hair data for carbon isotope values are all less than 1‰ (hair is corrected using the Crowley *et al.* (2010) collagen-keratin offset). The nitrogen isotopic values vary with a slightly larger magnitude, although the largest difference is only 1.7‰. Due to the small size of these changes I do not consider that there was any appreciable dietary change during the life time of these individuals. This supports what was seen at the population level in Chapter 7.

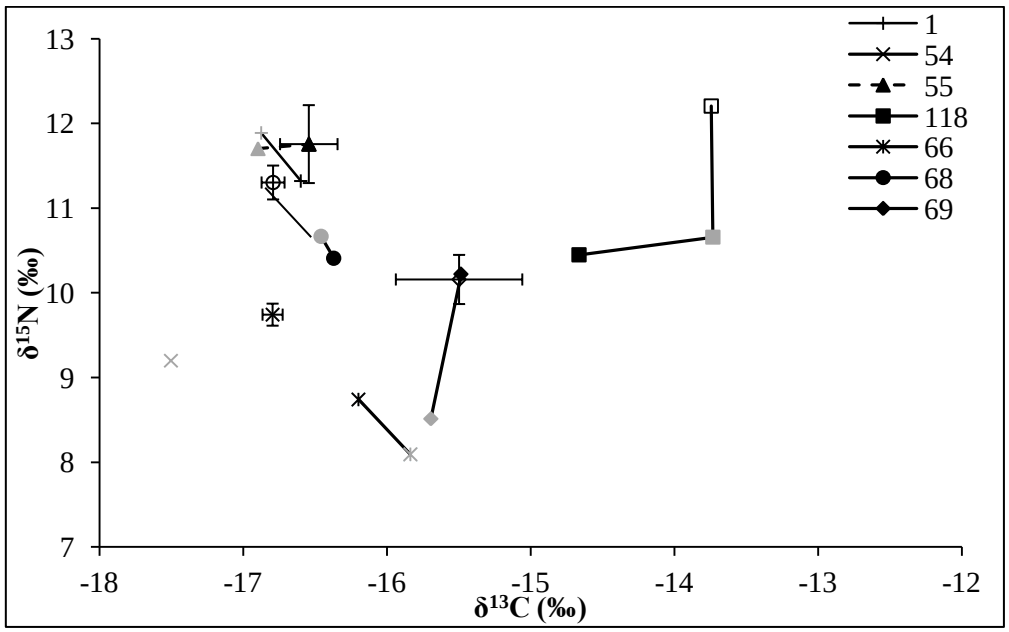

Figure 8.8 Life history isotopic data from individuals with more than one tissue type analysed. Black symbols represent tooth data, grey symbols bone data and open symbols hair data. In the case of Individual 54 the black cross represents hair data; for Individual 118 the open symbol represents skin data. Hair values have been corrected to collagen data using the collagen-keratin offset given by Crowley et al. *(2010). The mean segmented hair value has been plotted and the error bars represent one standard deviation away from the mean.*

Summary

In sum, the isotopic results suggest a diet based on both C_3 and C_4 resources with terrestrial meat as the main sources of protein. Marine foods would not have contributed significantly to the diet. Diet remained more or less constant throughout the year.

The issues highlighted for this period in Chapter 2 were specifically the evidence for an agricultural based diet and the evidence for social differentiation. For the former question the isotopic evidence is inconclusive. It is not possible to distinguish between domesticated and wild plants through isotopic analysis here because of the overlap in values between the two (Cadwallader *et al.* 2012). If the camelids with the highest $\delta^{15}N$ values are wild guanaco then there must have been a certain amount of hunting practised but it is difficult to confidently distinguish these animals from domesticated camelids foddered on water stressed plants. Hunting of wild animals is also suggested by the presence of the marine birds in the sample, which in turn suggests that the people exploited coastal resources, and probably the *lomas* which lies between Samaca and the coast. Hunting and agriculture are of course not mutually exclusive and it has been proposed elsewhere using the archaeobotanical and ethnobotanical data that this is the case for the lower Ica Valley (Beresford-Jones *et al.* 2011b). There is no clear evidence for social differentiation or any social identity transformations through the isotopic results, in the main due to the small sample sizes. There are hints at some possible divisions but without further samples it is not possible to draw any firm conclusions. The consistency of the diet along the length of the segmented hair values does not suggest a highly seasonally driven diet as might be expected with primarily hunter and gatherer groups, although there is isotopic variation along the length of the hair, which implies slight variation in food sources. This perhaps suggests that food was being dried and stored in order to ensure food security throughout the year, which in itself implies there was a surplus of foods, whether wild or domestic.

8.3 Early Intermediate Period

8.3.1 Fauna

Only two camelids were available for sampling for bone from this period, with one also providing a tooth sample. This latter animal has been aged as 6-9 months old based on tooth wear (Wheeler 1982). The bone isotope values were -14.9‰ and -14.7‰ for carbon and

9.6‰ and 9.0‰ for nitrogen respectively. The tooth sample had a $\delta^{13}C$ value of -15.3‰ and a $\delta^{15}N$ value of 10.6‰ and is paired with the latter of the two bone samples.

These values are considerably higher than the mean nitrogen isotopic value seen in the Early Horizon fauna (mean $\delta^{15}N = 7.2 \pm 1.8$‰) and are akin to those proposed for guanaco based on the isotopic values of the *lomas* plants (Thornton *et al.* 2011). However, the Early Intermediate Period population is hypothesised to be primarily agriculturalists, which is supported by many aspects of the archaeology (see Chapter 2). The results could be interpreted in a number of ways depending on whether the camelids are domesticated or wild. If the camelids were domesticated, then the high $\delta^{15}N$ values could have been due to manuring of plants, which has been proposed in other areas (Finucane 2007; Horn *et al.* 2009), that were later consumed by the animals. For example it is relatively easy to fodder camelids on the maize stubble after harvest (Finucane 2007) and it is a crop that the modern llama herders note as being one of the favourite of the animals.

Alternatively camelids, possibly guanaco, might have been consuming plants with high $\delta^{15}N$ values that are not consumed by the humans, such as *lomas* vegetation, seaweed or water stressed plants. Or, the camelids were juveniles and therefore the isotopic values could represent the milk-fed signal of a suckling infant, which is known to result in a higher $\delta^{15}N$ value (Katzenberg *et al.* 1996). One animal has been identified as being young enough to have still been consuming milk from its mother as weaning occurs naturally at about 9 months of age (Spalding 2010). The exact age of the other animal is unknown but given its isotopic values it is likely to have been of a similar age and therefore consuming, or have recently been consuming, its mother's milk.

This latter explanation is, I think, the most parsimonious and therefore these animals do not represent a typical isotopic signal from an adult domesticated camelid.

8.3.2 Humans

Bone, teeth and hair samples were taken from individuals from Cemetery 734. Out of 18 bone samples, only one was deemed unacceptable. One out of six tooth samples was not analysed as it was deciduous and all hair samples (n=4) were analysed - two for bulk values and two were segmented into 1cm sections (8 and 13 sections in total). The result of the last section from each individual was deemed unacceptable due to an insufficient amplitude.

Overall Population Diet

Bone

The mean $\delta^{13}C$ bone value for all individuals was -14.8 ±0.8‰, with a range of -16.2‰ to -13.3‰. The mean $\delta^{15}N$ value was 9.2 ±1.1‰, with a range of 6.9‰ to 12.0‰. The sample is comprised of both juveniles (three between the ages of 4 and 10 years old and one less than 3 years old) and adults (n=13) and there is no statistical difference between them for either carbon or nitrogen isotopes ($\delta^{13}C$ $t(15)= -0.11$, $p>.5$; $\delta^{15}N$ $t(15)= 1.51$, $p>.05$). Therefore the bone data can be treated as one entity. There are insufficient number of males and females to conduct a meaningful statistical analysis.

Tooth

The mean carbon isotope value of the five tooth samples analysed is -14.8 ±1.2‰, with a range between -16.5‰ and -13.3‰. The mean nitrogen isotope value is 8.7 ±1.0‰, with a range of 7.7‰ to 10.4‰. The carbon isotope values are almost identical to those from the bone data. The nitrogen isotope values have a smaller range and lower mean than the bone data, which may in part be due to the sample size. There are insufficient samples in order to compare the data by gender or tooth type. The samples were taken from first, second or third molars. The apices of the first molars were not closed and thus only represent the diet from 2.5-6 years. The highest $\delta^{15}N$ value cannot be ascribed to a weaning signal as it was from a third molar, which formed in adolescence.

Hair

The mean value for carbon isotopes for the four hair samples is -16.5 ±1.2‰, with a range between -17.7‰ and -15.2‰. For nitrogen the mean isotopic value is 9.1 ±2.3‰, with a range between 6.9‰ and 11.5‰. Again these are fairly similar to the values seen in the other tissues (Figure 8.9) although the standard deviation of nitrogen is larger.

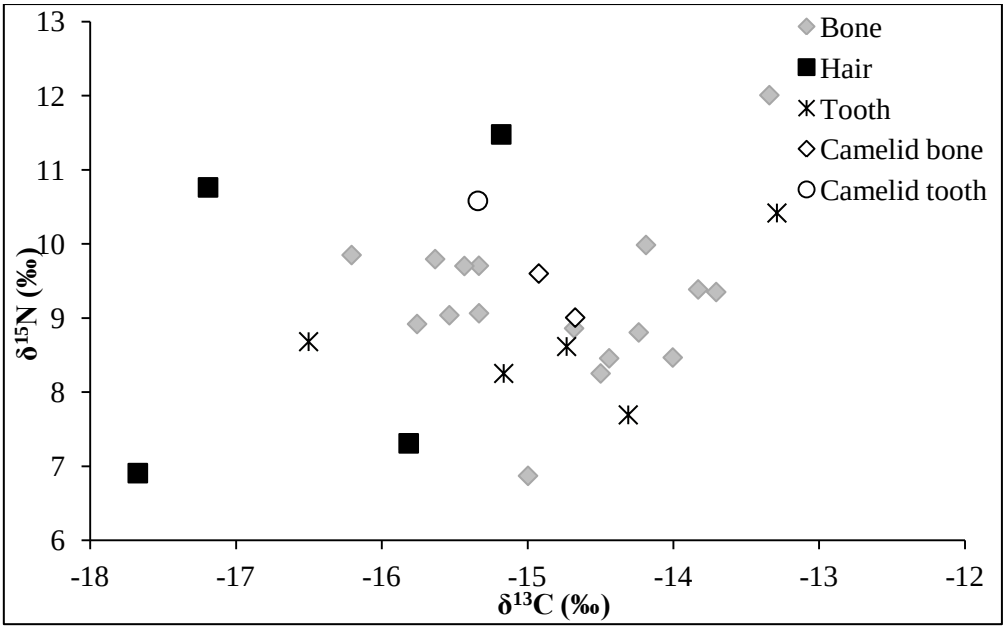

Figure 8.9 Isotopic data from all human and faunal tissue samples analysed from Cemetery 734.

The carbon results suggest a mixed C_3 and C_4 base to the diet supporting the hypothesis of an agricultural food regime (Beresford-Jones *et al.* 2011b). However, it does not have the scope to distinguish between wild and domesticated plants both of which could have caused the observed isotopic signal. In terms of nitrogen isotopes the camelid data plot well within the range of the human samples because of the young age of the animals. Thus the $\delta^{15}N$ position of the humans suggests they ate terrestrial meat, the amount of which varied between individuals. Thus the humans consumed a terrestrial based diet that included meat. The consumption of a significant amount of legumes (farmed *Phaseolus* spp. and gathered *Prosopis* spp.) may be partly responsible for the lowest $\delta^{15}N$ values as they have considerably lower nitrogen isotope values than other food resources and both have been found in midden contexts in numerous quantities (Beresford-Jones *et al.* 2011b). Along with maize as another plant source in the diet, this would have produced the observed mixed C_3/C_4 isotopic signals. However, it is not possible to elucidate the contribution of legumes to the diet without further analyses.

Seasonal Diet

Only two individuals from this cemetery can provide seasonal information from segmented hair samples. For Individual 107 twelve samples were successfully analysed. The variation in $\delta^{13}C$ values along the hair length is 1.1‰ and for $\delta^{15}N$ it is 1.0‰. For Individual 17, with

seven segments, there is more isotopic variation along the hair - 1.4‰ in carbon and 2.2‰ in nitrogen. These are both less than the value set by Webb *et al.* (2011b) to identify exploitation of multiple resources. However, the variation seen in Individual 17 only represents seven months and if a whole year's worth of hair growth was analysed it is possible that more variation may have been seen. As it stands there is insufficient data to suggest any exploitation of multiple production zones or highly seasonal diets.

Osteology and Pathology

A number of pathologies were observed in this sample, although the majority would not have affected the quality of life to any great extent. Plotting the bone values and two hair values it is clear that there is no real trend between those individuals with pathology and those without (Figure 8.10).

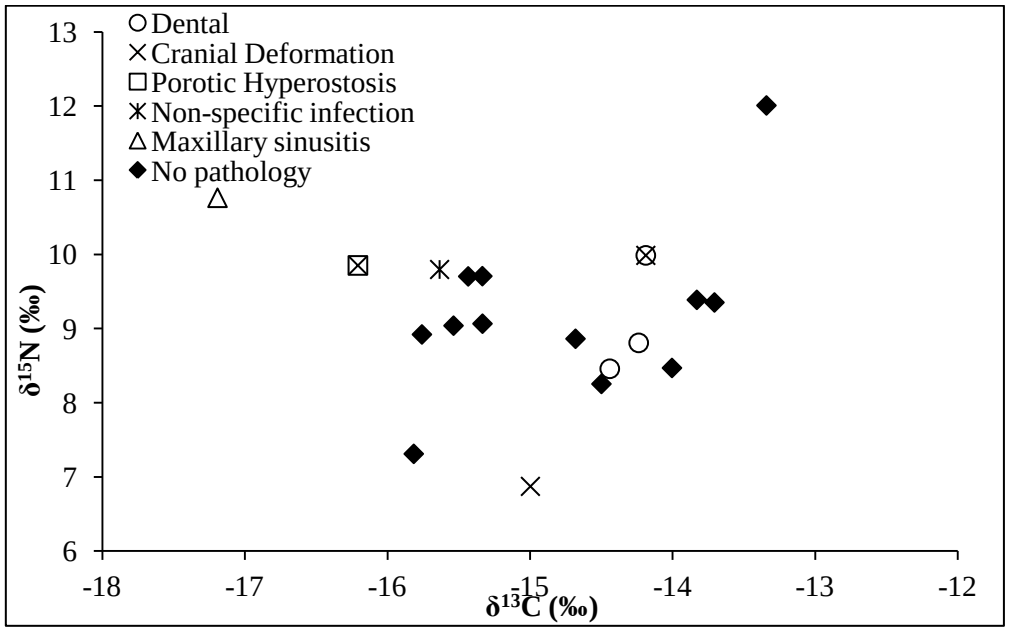

Figure 8.10 Isotopic results from the human data plotted according to the type of pathology observed on the skeletal material. The two hair values are the individual with maxillary sinusitis and the no pathology individual with the lowest $\delta^{15}N$ value. For individuals with more than one type of pathology, two overlapping symbols have been plotted.

The segmented hair results of Individual 17 are interesting with respect to their health before death. This individual was a juvenile, aged 6 ±2 years. Only the cranium was present with

many teeth lost post-mortem therefore no comments can be made on other indicators of physiological stress such as stunted growth or presence of linear enamel hypoplasias.

The hair values see a rise in $\delta^{15}N$ and $\delta^{13}C$ in the final 5cm of hair growth. $\delta^{15}N$ increases by 2.2‰ over this period and $\delta^{13}C$ by 1.4‰ (Figure 8.11). In nutritionally stressed individuals nitrogen isotopes have been observed to increase as the body is in a negative nitrogen balance and thus catabolism of the body's tissues occurs (Fuller *et al.* 2004; Fuller *et al.* 2005; Hobson *et al.* 1993; Mekota *et al.* 2006). This causes fractionation of the nitrogen akin to if one was consuming themselves and ascending the food chain. The isotopic range of nitrogen increases in the studies which analysed hair varied from no increase to approximately 2‰ (Fuller *et al.* 2004; Fuller *et al.* 2005; Mekota *et al.* 2006). Differences in the response of carbon isotopic values were noted by the different researchers and there is no clear consensus on what the expected reaction would be. The observed values in Individual 17 and the fact that this individual died in childhood are suggestive of a physiologically stressed individual.

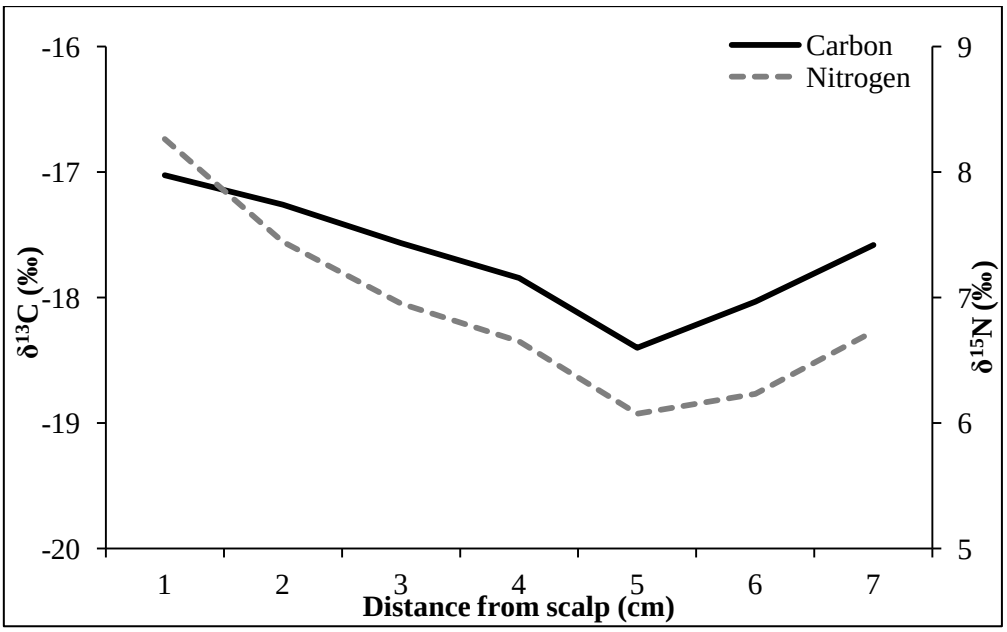

Figure 8.11 Segmented hair isotopic data from Individual 17.

An alternative explanation would be a change in diet, and given the increase in tandem in carbon and nitrogen isotopes an increase in marine foods would be a likely candidate. Marine resources did not appear to play a large part in the diet of the whole population (as evident in

the bone data) but tissues with long turnover rates such as bone will not register any short-term increases in a food type. Without more segmented data from which population seasonal trends can be identified it is difficult to rule this possibility out.

Life Histories

Analysis of the life history for this population in Chapter 7 did not produce a coherent view of the population due to the discrepancies between the paired and population data. Investigating the paired data (n=6) at a closer level, there is one individual (number 17, also discussed in the previous section) who had a substantial change in carbon isotope during their lifetime (Figure 8.12). The remaining six individuals had only minor variations of less than 1.1‰ in both carbon and nitrogen isotopes. Individual 108 who has the highest $\delta^{15}N$ values was a juvenile aged between 1 and 3 years and so this high trophic position is most probably a reflection of breast milk in the diet of this individual (Katzenberg *et al.* 1996). Individual 17 for whom there is a larger magnitude of change between the tissues was aged at 6 ±2 years. Due to the young age of the infant, the relationship between the tissues and the isotopic signal that they represent is different for the adults. The slow turnover of the bone represents diet of the infant over a longer period than the tooth, which formed between the ages of 2.5 to 6 years. Therefore the tooth and the hair are much more likely to represent the same dietary signal, which is what is observed here. The more positive $\delta^{13}C$ value of the bone sample may be due to different dietary inputs before the age of two and a half years, i.e. during the pre-natal phase, breast-feeding and weaning. The $\delta^{15}N$ values are fairly similar which does not imply a strong signal from breast milk (which would result in a higher nitrogen isotope value). However, this would be related to the nitrogen isotope value of the mother and the adult $\delta^{15}N$ values have shown a wide spread in this cemetery.

The individual life history data agree with the population level data, both suggesting that diet was constant throughout the life and no dietary changes whether socially induced or environmentally determined occurred.

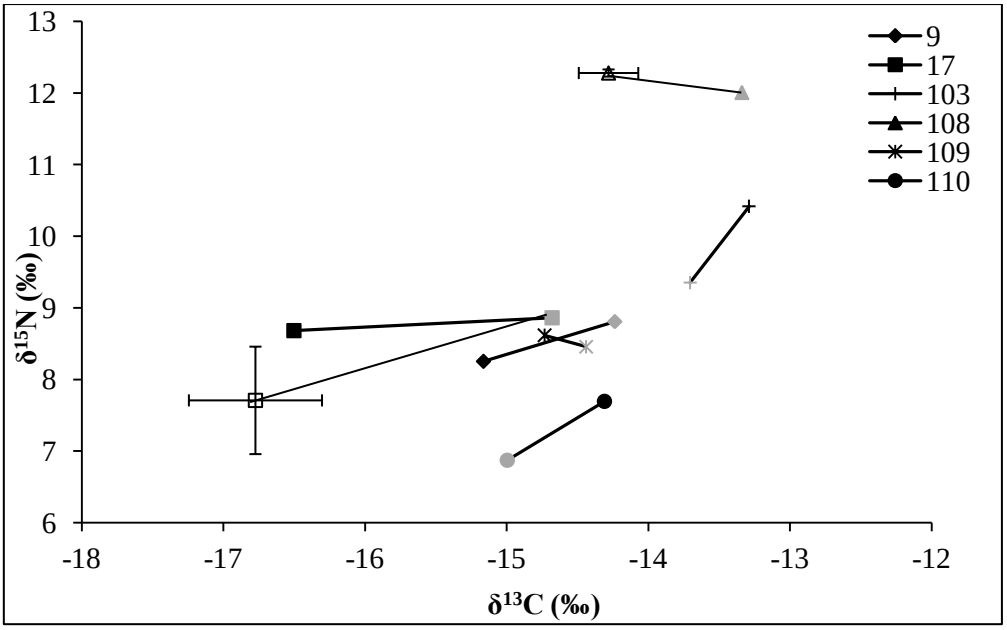

Figure 8.12 Isotopic life histories of individuals from Cemetery 734 with two or more tissue types. Black symbols represent tooth data, grey symbols bone data and open symbols hair data. Hair values have been corrected to collagen data using the collagen-keratin offset given by Crowley et al. *(2010). The mean segmented hair value has been plotted and the error bars represent one standard deviation away from the mean.*

There is also 'life history' information for one camelid sampled from this cemetery. A tooth and bone sample were taken from one animal aged 6 to 9 months based on dental wear (Wheeler 1982). The values for the bone sample are $\delta^{13}C$ = -14.7‰ and $\delta^{15}N$ = 9.0‰ and for the tooth sample $\delta^{13}C$ = -15.3‰ and $\delta^{15}N$ = 10.6. The carbon isotope values are within 1‰ of each other, which suggests that the plants that comprised the diet of the animal remained largely the same. Their nitrogen isotope values are 1.6‰ different between the two tissues. This is probably a reflection of the consumption of the mother's milk by the young animal. This would be reflected more in the still forming root but dampened in the bone signal which would have been formed during gestation (reflecting the mother's diet), with some reflection of the milk signal due to bone turnover since the birth of the animal.

Summary

Subsistence during the Early Intermediate Period is generally considered to be based primarily on agriculture. The isotopic values suggest a mixture of C_3 and C_4 resources, the majority of which were terrestrial. This supports what was recovered in the archaeobotanical

samples (Beresford-Jones *et al.* 2011b), with maize the domesticated C_4 plant and beans, wild tomatoes, fruits (guayaba, pacay etc) and squash all C_3 plants. In addition a suite of wild plants were recovered that are both C_3 and C_4 and therefore probably also contributed to the isotopic signal seen in the humans. The carbon isotopic base of the population is fairly wide (range = 4.4‰) suggesting that there is some diversity within the population as to whether their diet was more C_3 or C_4 based. Unfortunately contextual data for the individuals are very limited so that it is not possible to correlate dietary preferences with any other factors such as sex or social status. From these data it appears that the Late Nasca population broadly implemented the same subsistence strategy, which relied on terrestrial resources and a variety of plants. From the limited hair data there is no evidence for seasonality of diets nor movement of goods or people from other production zones.

8.4 Middle Horizon

8.4.1 Fauna

Bone and tooth samples from one camelid and one probable fox (*Lycalopex* sp.?) were analysed from Cemetery 398 and seven bone samples from camelids from Cemetery 755 (Figure 8.13). The eight camelid bone samples are normally distributed and have a mean $\delta^{13}C$ value of -15.8 ±2.5‰ and a mean $\delta^{15}N$ value of 7.1 ±1.1‰. The carbon isotope values range from -18.8‰ to -11.9‰ and the nitrogen isotope values range from 5.4‰ to 8.9‰. The one camelid from Cemetery 398 plots virtually at the mean of all the samples with values of -15.8‰ and 6.8‰ for carbon and nitrogen isotopes respectively. The tooth sample from this animal has a $\delta^{13}C$ value of -16.4‰ and a $\delta^{15}N$ value of 8.8‰.

The bone sample of the probable fox has a $\delta^{13}C$ value of -16.2‰ and a $\delta^{15}N$ value of 7.2‰. The tooth sample from this animal has a $\delta^{13}C$ value of -16.5‰ and a $\delta^{15}N$ value of 8.9‰. *Lycalopex* spp. are not true foxes but are canids closely related to dogs and wolves. They are omnivorous, often eating small birds, rodents, insect and fruits (Birdseye 1956). Given their omnivory it is surprising that the one example plots within the range of the herbivorous camelids for $\delta^{15}N$.

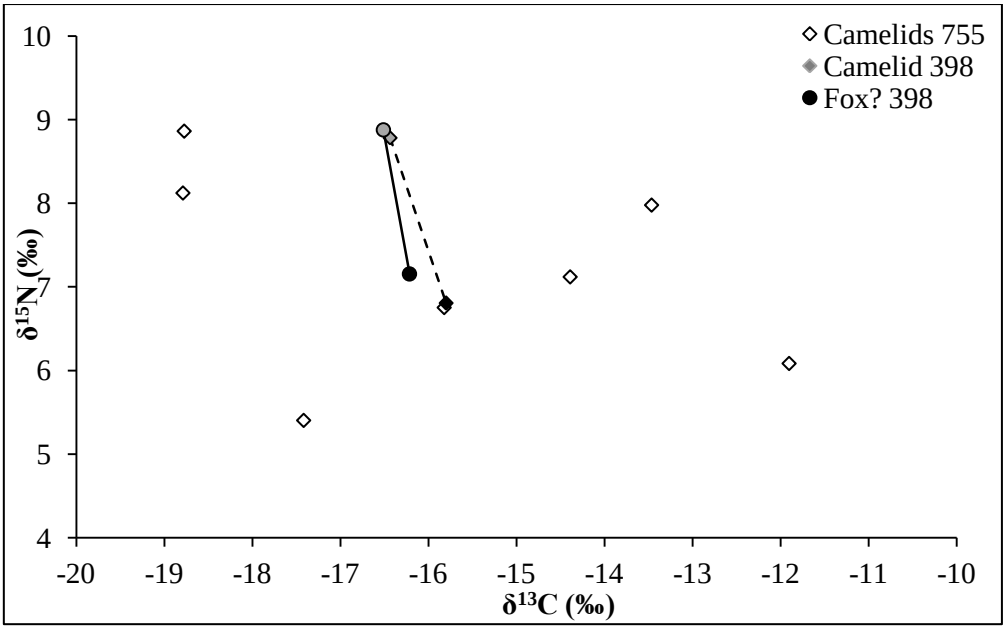

Figure 8.13 Middle Horizon faunal isotope data. Paired bone and tooth data are indicated by the dotted line, with bone represented by black symbols and tooth by grey symbols.

The carbon range of the camelids suggests that both C_3 and C_4 plants were consumed, with some animals consuming more of one type than another. This is suggestive of different foddering locations of the animals, although there is no clear division into separate groups. The nitrogen isotopic values are similar in range to those seen in the Early Horizon data and as such can generally be thought of as typical for terrestrial herbivores. The animals with the highest $\delta^{15}N$ are juveniles and as such a milk signal may be responsible for the higher values. Another potential reason is that these animals were part of trading caravans from another area, which had a C_3 plant base with a higher baseline nitrogen isotope value. For example from the Wari highland site of Conchopata camelids were analysed with carbon isotope values of approximately -19‰ and nitrogen isotope values of 8‰ (Finucane *et al.* 2006).

8.4.2 Humans

All four tissue types were analysed from human individuals from the two Middle Horizon cemeteries. All bone samples were successful in producing good quality collagen. Four tooth samples were not analysed as they were not suitable and two hair samples failed to produce acceptable results. The sample breakdown of acceptable results by tissues types for each cemetery is given in Table 8.3.

Table 8.3 Breakdown of human samples successfully analysed from the two Middle Horizon cemeteries.

	Cemetery	
	398	**755**
Total number of individuals	19	21
Bone	18	19
Hair	16	9
Tooth	17	14
Skin	4	4

Overall Population Diet

The results from the four tissue types agree well in terms of the spread of data and the ranges of the data for both carbon and nitrogen isotopes as shown in Table 8.4 below. In addition the two cemeteries are very similar to each other, but the distribution of the population within the ranges is somewhat different for carbon but not nitrogen isotopes. For $\delta^{15}N$ the population in general can be considered as a trophic step above the camelid mean of 7.1‰ (ignoring the skin as it is unknown why the $\delta^{15}N$ values are elevated compared to other tissues (see Chapter 7)). Thus the protein source of the population is of a terrestrial origin. Some individuals have relatively low $\delta^{15}N$ values, close to the camelid mean. The actual spread of the camelid nitrogen isotope values is quite large (±1.1‰, 1σ) and so the people with low nitrogen isotope values may have been consuming lower nitrogen camelids. The amount of meat consumed may also have been small for these individuals compared to the rest of the population. The isotopic difference in nitrogen between infrequent and daily meat consumers has been shown to be 1.5‰ (O'Connell and Hedges 1999a). Alternatively, these individuals could have had no access to meat or animal products of any kind or consumed large amounts of legumes, as has already been proposed for some Late Nasca individuals.

For Cemetery 398 the group is evenly spread across the range in carbon isotopic values whereas for Cemetery 755 the population forms clusters evident in bone, hair and tooth data (see Figures. 8.14 and 8.15). Given that these tissues reflect the protein portion of the diet and the spread of the camelid data it could be surmised that the different groups in Cemetery 755 selectively ate camelids who had been reared in certain locations. Alternatively, there was a disparity in the amount of C_3 and C_4 plants consumed by the population. The clustering of the groups can be investigated further using statistics to compare the differences in means, e.g. *t*-tests, ANOVAs, as well as multivariate tests using principal component analysis.

Table 8.4 Average values for each tissue in each cemetery and for the cemeteries combined. Means and standard deviations are given in all cases where the data are normally distributed and corresponding statistical significances refer to t-tests comparing the two. For data not normally distributed (marked with an asterisk), the median and inter-quartile range is given and a Mann-Whitney test was conducted comparing the two cemeteries.

	398			755			Combined		Stat. sig.
	n	**$\delta^{13}C \pm 1\sigma$ (‰)**	**$\delta^{15}N \pm 1\sigma$ (‰)**	**n**	**$\delta^{13}C \pm 1\sigma$ (‰)**	**$\delta^{15}N \pm 1\sigma$ (‰)**	**$\delta^{13}C \pm 1\sigma$ (‰)**	**$\delta^{15}N \pm 1\sigma$ (‰)**	
Bone	18	-13.6 ±1.3	9.5 ±0.7	19	-12.7 ±2.3	9.3 ±0.8	-13.1 ±1.9	9.4 ±0.8	C & N: $p>.05$
Tooth	17	*-14.9 -15.5 to -13.6	9.8 ±0.8	14	-13.3 ±2.1	9.5 ±0.8	-13.8 ±1.8	9.7 ±0.8	C & N: $p>.05$
Hair	17	-14.0 ±1.7	8.9 ±1.2	9	-13.8 ±2.5	9.2 ±1.2	-13.9 ±1.9	9.0 ±1.2	C & N: $p>.5$
Skin	4	-13.9 ±0.5	12.3 ±0.7	4	-13.4 ±1.5	12.7 ±1.2	-13.7 ±1.1	12.5 ±0.9	C & N: $p>.5$

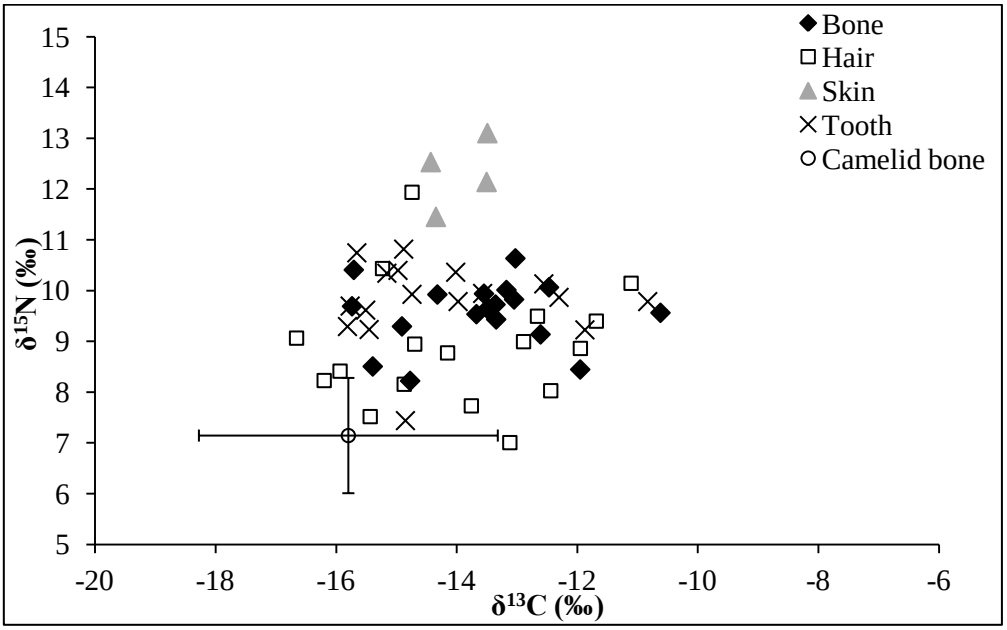

Figure 8.14 Isotopic results from all tissues taken from human individuals from Cemetery 398. The camelid mean bone value is also given. The error bars represent one standard deviation.

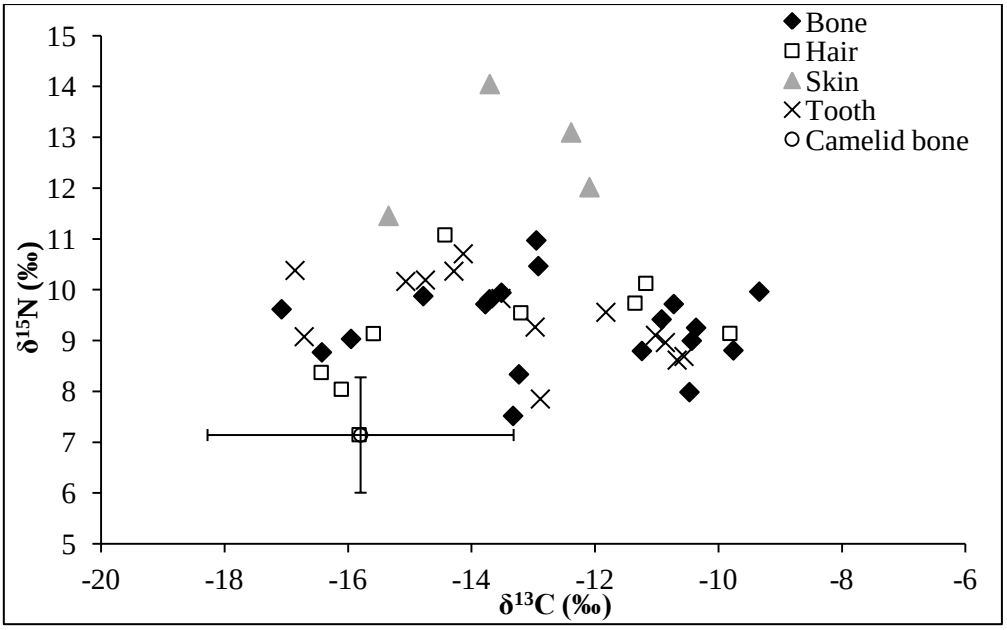

Figure 8.15 Isotopic results from all tissues taken from human individuals from Cemetery 755. The camelid mean bone value is also given, with error bars representing one standard deviation.

Bone

Principal component analysis on the bone data identifies that age (adult or juvenile), sex (male, female or juvenile) and carbon isotopic value account for 51% of the variation seen in the data, and to a lesser extent cemetery and nitrogen isotopic value (22%). Plotting the PCA scores of these two components, three main groups are evident, which I have also identified using Cluster analysis on the data (Figures 8.16 and 8.17). Cluster 1 are adults from both cemeteries; Cluster 2 are juveniles from both cemeteries; Cluster 3 are adults from Cemetery 755. This is corroborated with a Kolmogorov-Smirnov Z test carried out on the data between adults and juveniles which showed for the combined cemeteries there was a significant difference between the two groups in carbon isotopes (KSZ= 1.8, $p<.01$) and a *t*-test between the adults from each cemetery that also shows there is a significant difference in carbon isotopes between the two groups ($t(25)= -3.4$, $p<.01$). The statistical tests show there is no difference in nitrogen isotopes, although this has been identified as important in the second principal component. Cluster 1 and 2 can be distinguished from Cluster 3 in the PCA based on the second component. Taking the mean nitrogen isotope values of these clusters, this is apparent, with the mean values of 9.7‰, 9.4‰ and 8.9‰ for Clusters 1,2 and 3 respectively (Figure 8.18).

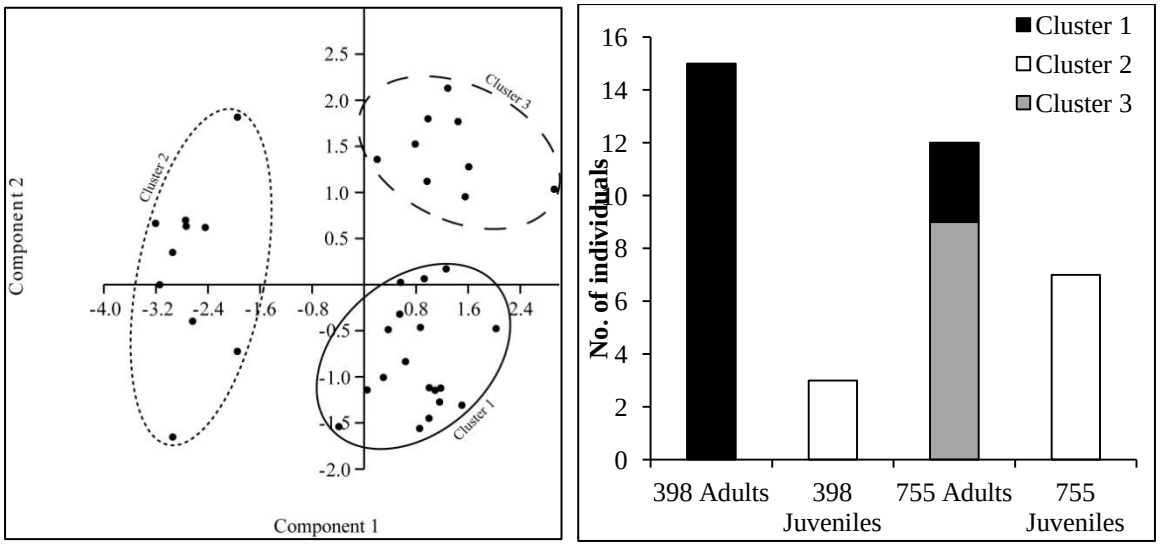

Figure 8.16 (left) PCA plot of individuals scores in the first and second components. All available variables (cemetery, age, sex, isotope values) were used for the analysis. Clusters identified through cluster analysis are shown. Figure 8.17 (right) Distribution of adults and juveniles into the different clusters identified based on the PCA scores.

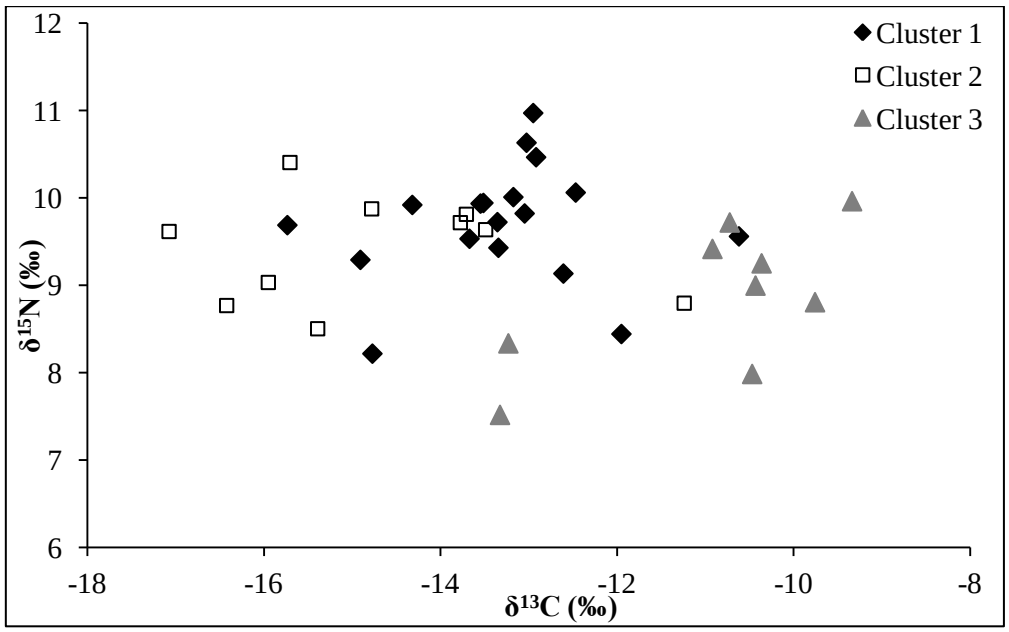

Figure 8.18 Bone isotopic data from both Middle Horizon cemeteries plotted in the clusters identified through a combination of PCA analysis and Cluster Analysis.

In sum, the bone data can be split into three groups. For Cemetery 398 this is a division based on adults and juveniles. For Cemetery 755 this split is evident too but the adults also separate

into two groups. Of these two groups, all the female adults (n=3) are in Cluster 3 and the males are split approximately equally between Clusters 1 and 3 (n=3 and 5 respectively), one adult of unknown sex falls into Cluster 3.

Tooth

Using principal component analysis on the tooth data has identified different principal components to bone as being responsible for the variation in the data. The first principal component highlights carbon isotopes, nitrogen isotopes and tooth type as being highly important and the second component identifies the cemetery and sex as important factors. Together these two account for 58% of the variation. As all of the teeth were formed during childhood, the data could not be divided into adult and juvenile categories, hence the disparity in difference with the bone data. The PCA scores from the teeth do not clearly plot into clusters when presented in a scatter plot. However, using Ward's Method of clustering I can identify two groups (Figure 8.19), which when plotted divide largely based on isotope values (Figure 8.20).

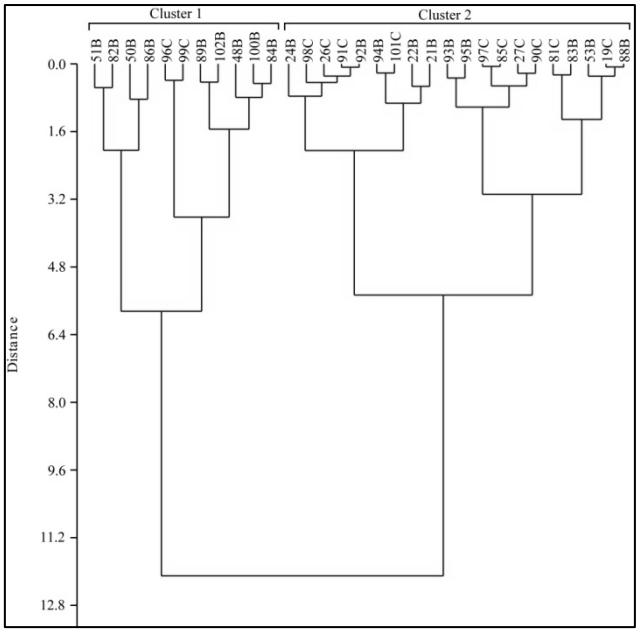

Figure 8.19 Dendrogram from Ward's Method of cluster analysis based on the PCA scores from the tooth data. The two clusters have been identified based on the length of the branches connecting the individuals and similarity of distance from the origin for the two groups.

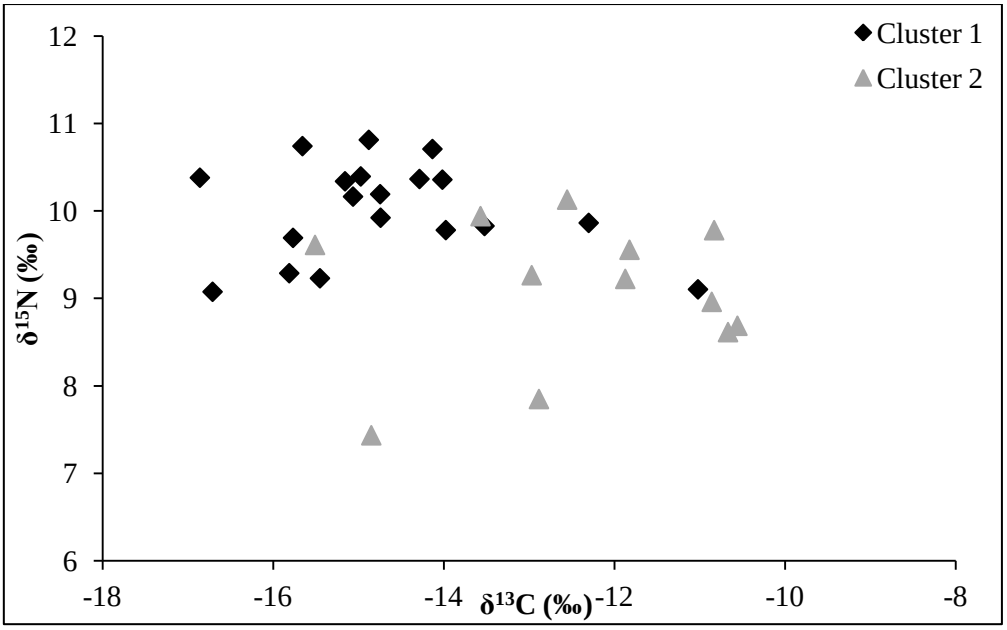

Figure 8.20 Tooth isotopic data plotted in the clusters identified above.

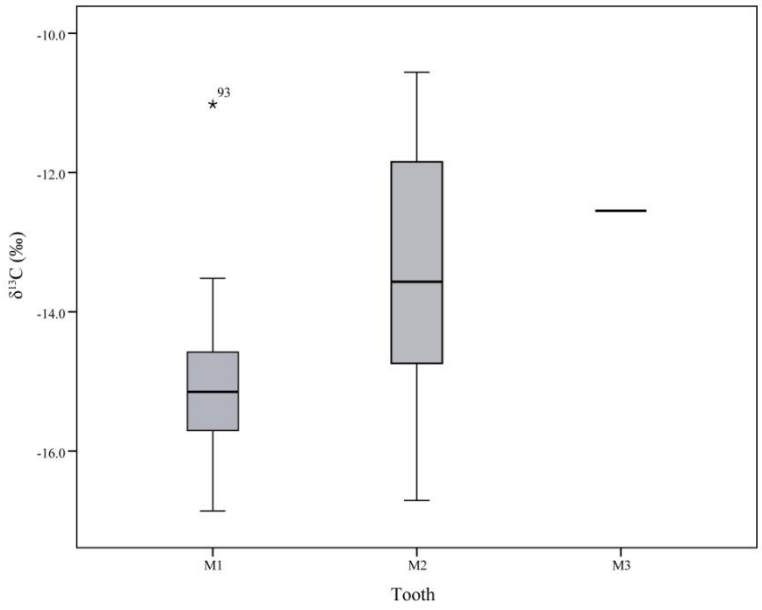

Figure 8.21 Carbon isotope values by tooth type sampled.

This agrees with the observations from the distribution curves in Chapter 7 where a bimodal carbon isotopic distribution was observed. For Cluster 1 the mean values are -14.7 ±1.4‰ for $\delta^{13}C$ and 10.0 ±0.5‰ for $\delta^{15}N$. For Cluster 2 they are -12.4 ±1.6‰ and 9.1 ±0.8‰ for carbon and nitrogen respectively. It is interesting to note that the tooth type is also an important

factor in this clustering. All of the data from the 1st molars (n=11) fall into Cluster 1 with approximately half of the data from the second molars (n=8). The rest of the second molars (n=11) and the third molar (n=1) data fall into Cluster 2. The dietary period, i.e. age in years, represented by the tooth increases from first to third molar. The carbon values also increase with the tooth type supporting the idea of the sub-adult diet being depleted in carbon compared to the adult diet. This relationship is confirmed through correlation of the two variables, which shows a significant relationship (τ= .41, p<.01), which is evident when a box plot of the data is plotted (Figure 8.21).

Hair

Principal component analysis of the hair data gives similar results to bone, although carbon isotope is now counted in the first component as important and hair length in the second component has a minor influence. The results pull out the juveniles as a separate group from the adults, regardless of cemetery. This confirms the results of the *t*-tests, which found carbon isotopes significantly different for adults and juveniles but not nitrogen isotopes ($t_{carbon}(21)$= -3.7, p<.001). Therefore there are two independent statistical tests which demonstrate the importance of carbon isotopes and age (adult v juvenile) in the grouping of the hair data (Figures 8.22 and 8.23).

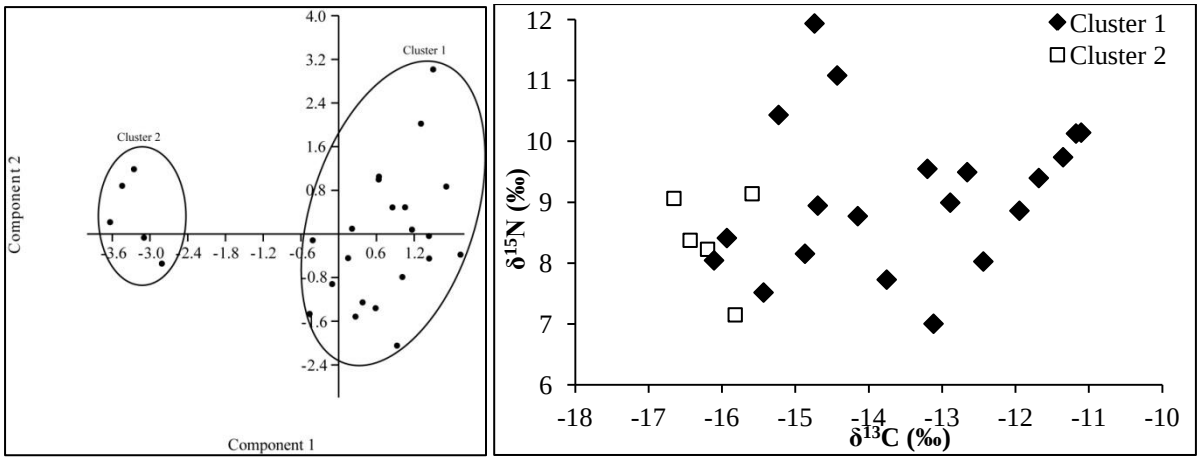

Figure 8.22 (left) PCA plot of hair isotope values by the first and second component. The cluster have been identified using cluster analysis. Figure 8.23 (right) Hair isotopic data plotted by cluster.

Skin

Analysis of the skin data using the same methods produces similar but not identical results to the other tissues. Through principal component analysis once again age, sex and carbon isotopes are identified as being the most important components in explaining the variation in the data. The juveniles are clearly separated in this method, but using cluster analysis to define the clustering of the PCA scores, the juveniles are grouped in with two adults (Figure 8.24). The cluster groups identified are divided into individuals with lower $\delta^{13}C$ and lower $\delta^{15}N$ values and those with more enriched values, although they all plot within 3‰ of each other for carbon isotopes and 2‰ for nitrogen isotopes (Figure 8.25).

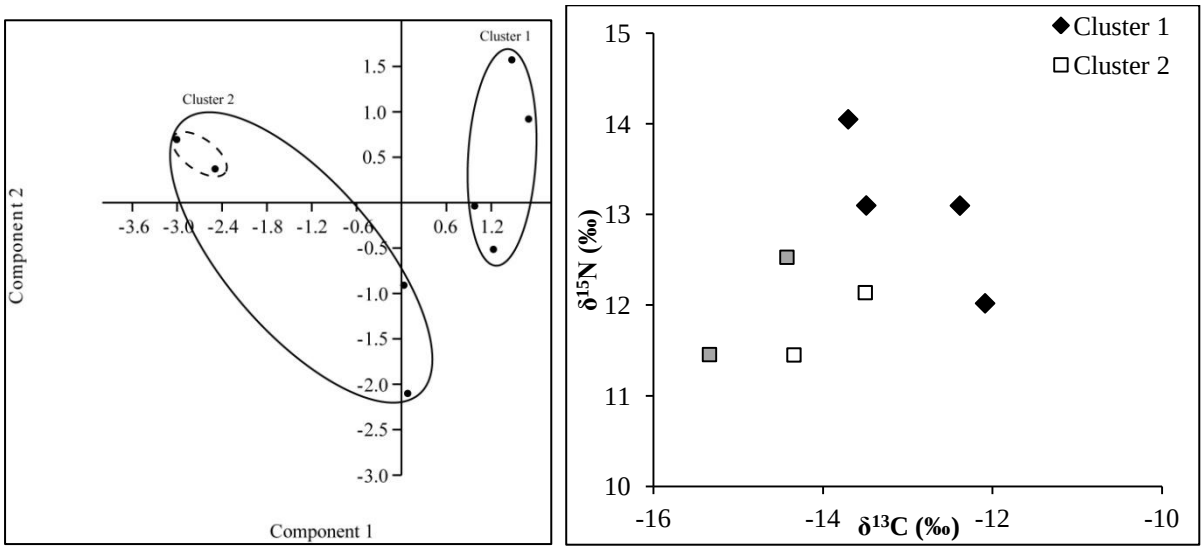

Figure 8.24 (left) PCA analysis of the skin data plotted by the scores for the first and second components. Juveniles are in the dashed circle. Solid circles are the groups identified by cluster analysis that was conducted on the PCA scores. Figure 8.25 (right) Skin isotopic data plotted in its clusters. The two juveniles are the grey shaded squares.

In sum, the analysis of the dietary data at the population level reveals that in all tissues the juveniles are different from the adults. There are additional differences between adults in Cemetery 755, expressed in bone, although these are not related to sex differences. These differences are more apparent in the carbon isotope values in every tissue.

Seasonal Diet

In order to investigate seasonal diets the variation in the segmented hair samples can be used. A range of variation along the length of the hair is seen for both carbon and nitrogen. A total of 21 individuals were subject to segmental analysis (n_{398}=14, n_{755}=7), with the number of 1cm segments ranging from five to forty. The majority of the total hair lengths are between 10cm and 20cm in length (n=12). For carbon isotopes the variation along the hair length of an individual ranged from 0.8‰ to 4.7‰, with a median of 1.2‰ and an interquartile range of 1.0‰ to 2.3‰. For nitrogen the isotopic variation ranged between 0.5‰ to 2.7‰, with a median of 0.8‰ and an interquartile range of 0.6‰ to 1.5‰.

Statistical tests reveal that the variation in one isotope is somewhat explained by the variation in the other isotope, with the number of segments potentially also having an impact. Principal component analysis shows that the important variables are whether the individual is adult or juvenile, the number of segments the hair was cut into and the range of both carbon and nitrogen isotopes. As with the data used to discuss the diet of the population, the juveniles are separated out.

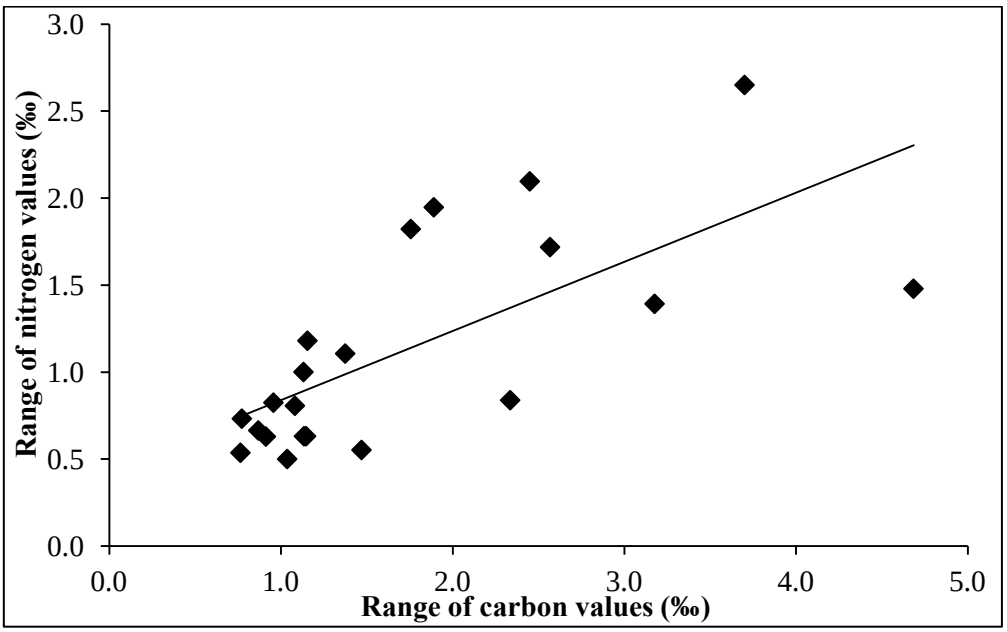

Figure 8.26 Correlation between the carbon and nitrogen isotopic ranges in the segmented hair samples from the two Middle Horizon cemeteries. The r^2 *value of the line is .50.*

Stepwise linear regression agrees to some extent with the findings of the principal component analysis. To explain the variation in the carbon range, the number of segments and the nitrogen isotopic range are the most important variables (67% total) but the variation in the nitrogen isotopic range is best explained solely by the carbon isotopic range (48%). A partial correlation between the carbon and nitrogen isotopic ranges controlling for the number of segments produces a significant relationship with $r^2 = .50$, $p < .001$, supporting this observation (Figure 8.26).

The lack of influence the number of segments has on the nitrogen isotopic range is evident when the isotopic ranges are plotted by hair length (Figure 8.27). Carbon isotopes are clearly correlated more strongly than nitrogen isotopes. Both are statistically significant but nitrogen is only just so with a p value of .05 (using Spearman's rho: $\rho^2_{carbon} = .23$, $p < .05$ and $\rho^2_{nitrogen} = .19$, $p < .05$).

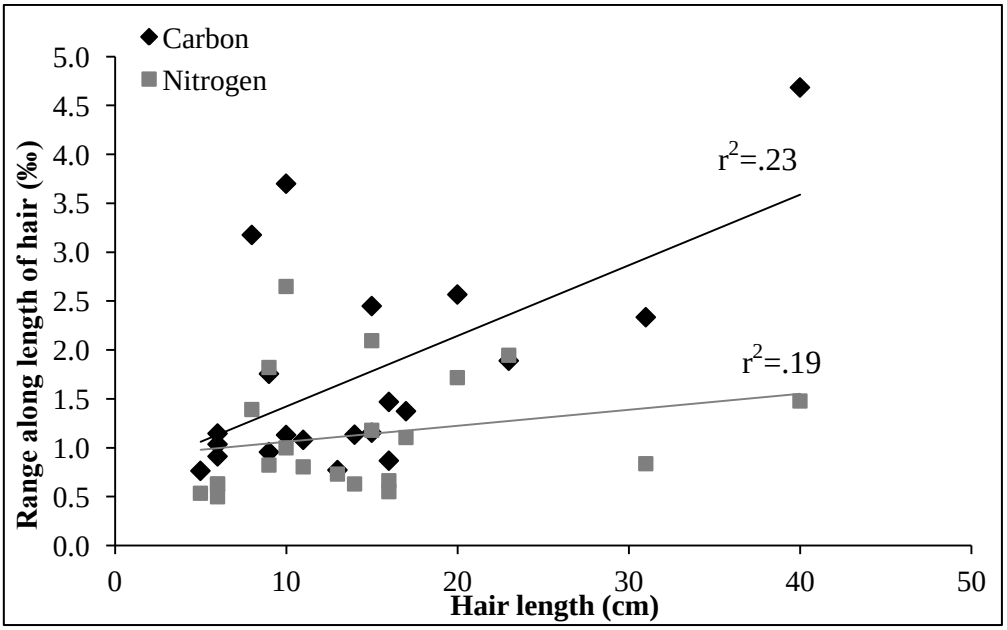

Figure 8.27 Correlation of the range in carbon and nitrogen isotopes seen along the length of the hair with total hair length.

Thus the longer the hair the more carbon isotopic variation, and the more carbon variation the more nitrogen isotopic variation. In order to investigate seasonal diets without biasing the interpretation due to hair length effects, only individuals with hair lengths longer than 12cm,

i.e. 12 months of growth shall be considered. This should encompass the full range of any seasonal variation along the length of the hair rather than only partially capture it as may be the case with shorter hair lengths.

Eleven individuals have hair that represent at least twelve months of hair growth. This group contains only adults, as well as three samples from hair pieces (see Appendix 6 for details on the hair pieces). The $\delta^{13}C$ range in an individual's hair varies from 0.8‰ to 4.7‰, with a mean range of 1.9 ±1.1‰. The nitrogen isotopic ranges vary from 0.6‰ to 2.1‰, with a mean range of 1.2 ±0.6‰ (Figure 8.28).

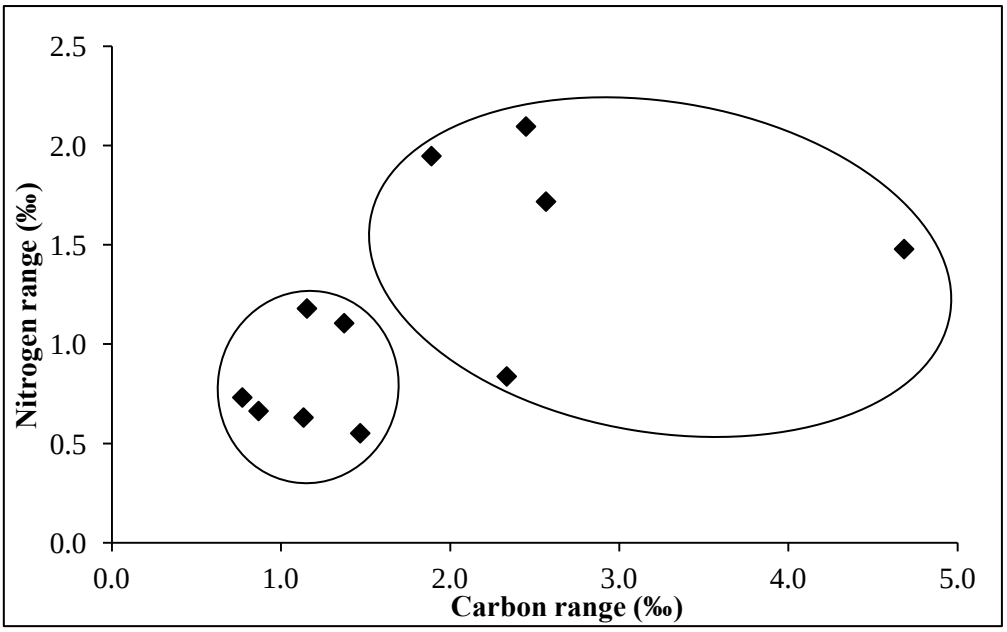

Figure 8.28 Isotopic ranges in hair samples at least 12cm in length. The circles indicate the groups identified by cluster analysis, which was based on the ranges of the two isotopes for each individual.

There is a difference in variation along the length of the hair between the individuals, which may be due to differing subsistence strategies. Following ecological models, high variance would suggest a generalist strategy, i.e. a diet that varies the isotopic dietary source considerably over time, and low variance suggests specialist strategies, i.e. a diet which concentrates on a limited range of food types only (Bearhop *et al.* 2004). Webb *et al.* (2011b) used the criterion of carbon isotopic ranges higher than 2.5‰ as indicative of exploitation of multiple production zones, which can be considered as generalist in dietary terms but may

have specialist social connotations. Using cluster analysis (Ward's methods), I have been able to split the individuals into two clusters which approximately adhere to a split at 2‰ variation in carbon isotopes (Figure 8.28). The isotopic data for the other tissues (bone, tooth and skin) from these eleven individuals are all very similar to each other, and thus the hair isotopic data have identified groupings that were not otherwise visible.

The group (n=6) with low amounts of isotopic variation (<1.5‰) along the length of the hair are considered as having a constant diet over the course of a year (trend 1, Figure 8.29). The individuals vary in carbon values between approximately -16‰ to -12‰ and between 7‰ and 10‰ for nitrogen. All of these individuals fall in the range of a mixed C_3 and C_4 terrestrial diet.

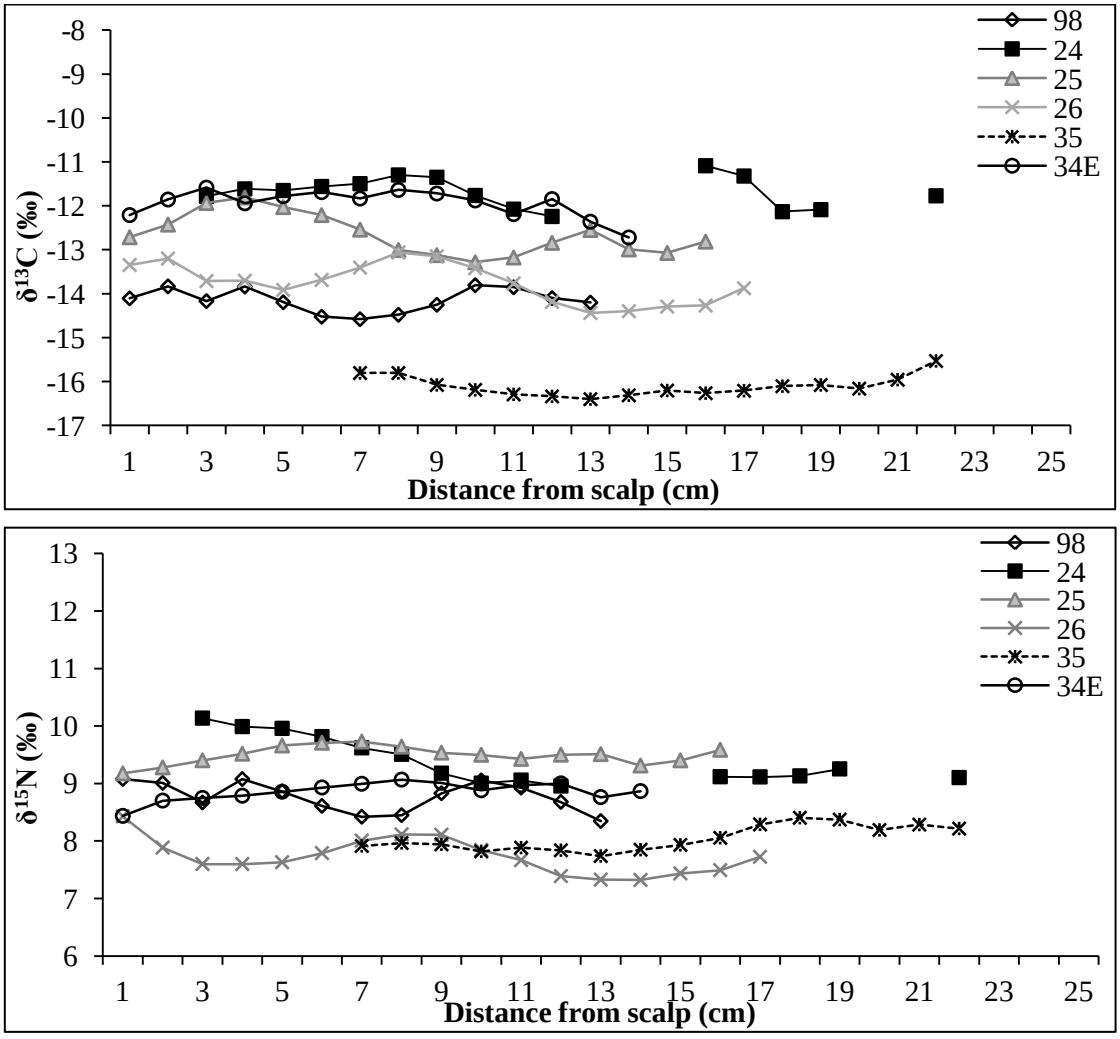

Figure 8.29 Carbon (top) and nitrogen (bottom) isotopic data for segmented hair samples with less than 1.5‰ variation in carbon along the length of the whole hair.

Some isotopic variation is evident along the length of the hair but given it is less than 1.5‰ it cannot be differentiated from natural environmental variation. This trend can be explained in several ways. The first and most parsimonious explanation is that the constancy in diet may be a result of food storage and provisioning. Food would have been needed to be regulated and controlled so that there was always the same type of resources available in more or less the same amounts (i.e. no variation in meat consumption). The presence of the Wari therefore induced long-term food management strategies. The need for food management at this time could also be attributed to the instability of the environment, which may have introduced uncertainty in production and therefore increased the need for food security. Another possible reason could be a regular and unchanging supply of imported food resources from outside that valley that were specially reserved for this subset of individuals. Based on the carbon and nitrogen isotope values alone it is not possible to postulate what type of foods or where they originated from. This could be taken as evidence for the presences of a highland support mechanism for the hinterlands, or as the regulation of hinterland food resources by the Wari heartland elites. The evidence for both explanations will be discussed further in due course. Alternatively the environment could have been much more conducive to agriculture than previously thought (Beresford-Jones *et al.* 2011b; Eitel and Mächtle 2009) meaning these individuals had no issues with food management and had a range of plant and meat resources always available. However, this hypothesis cannot be supported without further evidence for a better environmental setting in the Middle Horizon.

Five individuals have much higher levels of isotopic variation along the length of the hair in both carbon and nitrogen. The trends seen in these data can be divided into two types: a) regular cyclical changes that form a sinusoidal shaped line with carbon and nitrogen isotopes correlated in their increases and decreases (Individuals 21 and 94), henceforth trend 2; and b) irregularly shaped lines that show increases and decrease in the isotopes, which are not necessarily correlated between the two isotopes (Individuals 22, 34 and 101), henceforth trend 3 (Figure 8.30). The carbon values fall within the range of approximately -16‰ to -10‰, with intra-individual variation ranging from 1.9‰ to 4.7‰. The nitrogen values range from approximately 7‰ to 12‰ for these five individuals, with intra-individual ranges of 0.8‰ to 2.1‰.

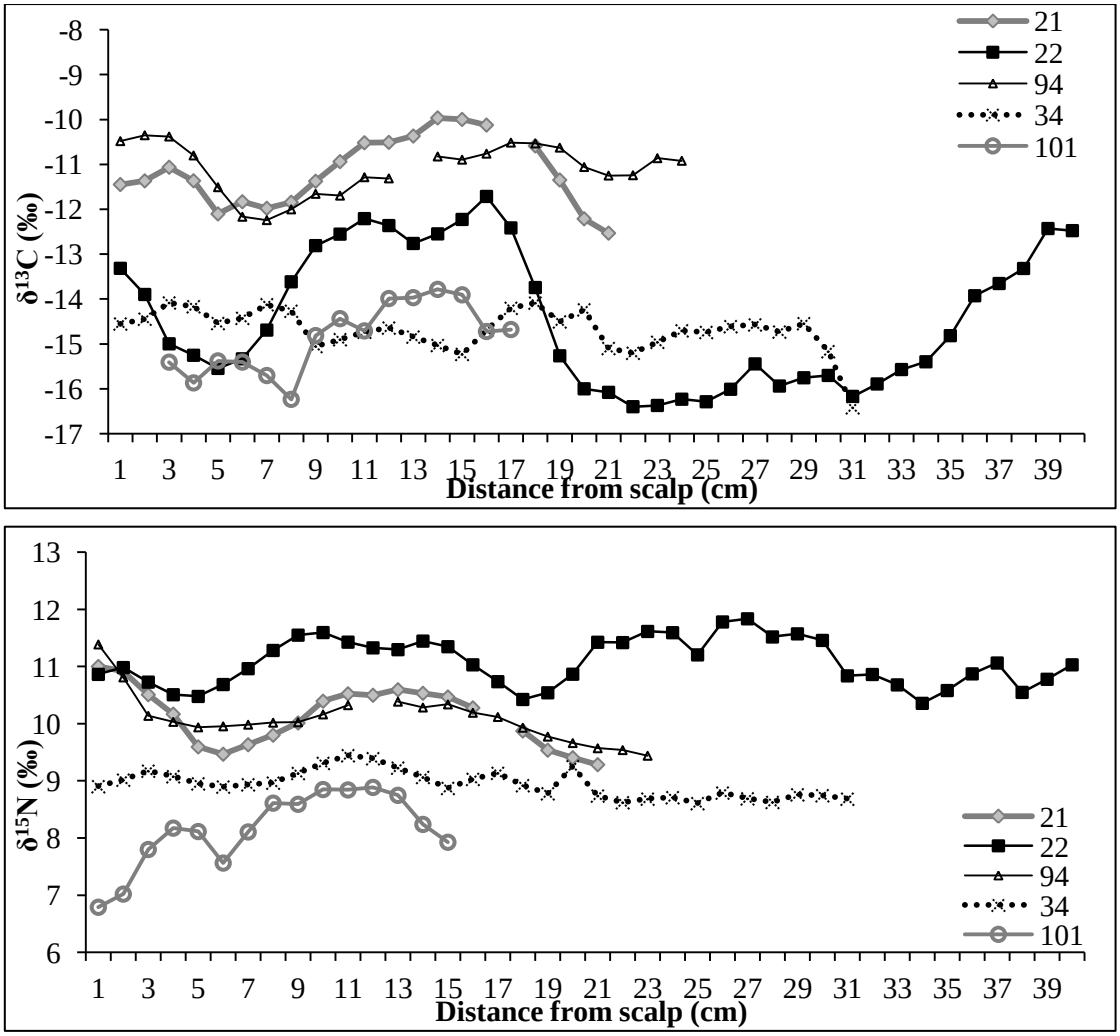

Figure 8.30 Carbon (top) and nitrogen (bottom) isotopic analysis of segmented hair samples with more than 1.5‰ variation in carbon along the length of the hair.

Trend 2

Following Webb *et al.* (2011b) these signals would be interpreted as constant movement over two or more production zones. Given that the shapes of the curves are regular and sinusoidal I would argue that an alternative explanation would be a resident population with a highly seasonal diet, with specific resources consumed at specific times of the year, similar to the idea of generalists used in ecological modelling (Bearhop *et al.* 2004). The number of months between the peaks and the troughs varies between about five and seven months.

Trend 3

The isotopic shifts are not as regular in this trend, which would suggest that a seasonal subsistence was not practised. There is some correlation between the nitrogen and carbon isotopes but this varies between individuals. The shifts are followed by a period of constant isotopic values, which vary in duration, before another shift. The explanations for this trend are similar to those for trend 2 - local diets highly affected by the local growing conditions or exploitation of multiple production zones. This latter reason would not be a regular exploitation but one punctuated by periods of constant diets (in the isotopic sense). A third explanation particularly applicable to Individual 101 would be relocation to a different environment.

Highly Seasonal Diets

The hypothesis for a highly seasonal diet is derived from the high potential for both C_3 and C_4 resources to be sourced from the local environment. This type of dietary shift - between the different photosynthetic pathways - should be clearly visible in segmented hair samples at the seasonal scale and has been observed in hair or wool from animal populations (Ayliffe *et al.* 2004; Cerling *et al.* 2004; Witt *et al.* 1998). Changes in carbon isotopes have been noted in a Nubian population inhabiting a C_3/C_4 desert environment, with a variation in the hair of up to 3‰ over a six month period (White 1993). These were interpreted as seasonally induced dietary changes, yet this study analysed on short (<12cm) lengths of hair and thus did not observe a cyclical cycle as seen here.

It is clear from the archaeobotanical record from the Samaca and Ullujaya basins (Beresford-Jones *et al.* 2011b) and from modern day farming in the basins that crops such as beans, squashes and maize can all be successfully grown in the environment through irrigation farming. Irrigation canals were established at least as early as the Early Intermediate Period and, although there is a lack of domestic crops in the limited archaeobotanical record for the time, the possible local production of these crops should not be immediately dismissed. Maize is a nutrient hungry plant and therefore inter-cropping with soil enrichers such as beans or squashes may have been practised when replenishment from river silts was not sufficient (Beresford-Jones 2011). Alternatively there are a wide variety of edible C_3 and C_4 wild plants which could have been exploited seasonally (Cadwallader *et al.* 2012).

Exploitation of Multiple Production Zones

The isotopic variation in plants in different areas is caused by variations in the natural environment, such as water availability, insolation, temperature and altitude, which can affect both the $\delta^{13}C$ and $\delta^{15}N$ values (Körner *et al.* 1988; Sparks and Ehleringer 1997; van de Water *et al.* 2002; Vitousek *et al.* 1990; Vitousek *et al.* 1988; Wang *et al.* 2008). Additionally, as altitude increases and conditions become colder and wetter the proportion of C_3 to C_4 plants changes, with the former becoming more dominant (Ambrose 1993; Ehleringer and Björkman 1977). Thus not only will the plants have a different isotopic signal in different regions but so too will the local fauna that feed upon those plants. In theory, then, consumption of resources from higher altitudes would be reflected in a decrease in $\delta^{13}C$ values. It is difficult to predict the $\delta^{15}N$ changes as these can be affected by human activities such as manuring, which has been suggested as being practised in the highlands during the Middle Horizon (Finucane 2007). Exploitation and consumption of marine resources would cause an increase in $\delta^{15}N$ values due to the elevated position of the marine food chain relative to the terrestrial one. An increase in $\delta^{13}C$ may also be caused as marine foods in general have higher carbon values. However, if the population seasonally shifted from a C_4 terrestrial diet towards a more marine diet then there may be no discernible change in $\delta^{13}C$. A clear correlation in both carbon and nitrogen values can be seen in some individuals (e.g. Individuals 21 and 94) with the two isotopes rising and falling in tandem.

The exploitation of multiple production zones is also an intriguing possibility to explore. Firstly to understand the need or desire of the population to consume non-local resources, and secondly, because it is unknown if the people were moving between the production zones or the food was being transported to the lower Ica Valley. Thirdly, trend three raises the possibility of irregular exploitation of multiple zones.

The consumption of non-local resources can be viewed as either biologically or socially driven. Biologically, this implies that the local food resources are inadequate and supplements to the diet must be found. It has been argued that the environmental conditions were becoming increasingly arid from the end of the Early Intermediate Period and into the Middle Horizon (Eitel and Mächtle 2009) and archaeobotanical work in the lower Ica Valley has shown a near absence of domesticated plants from this period (Beresford-Jones *et al.* 2011b). It is easy to conclude that the populations were forced to seek resources in other production zones. However, the individuals with a stable diet (trend one) suggest that food

provisioning was taking place and that food was being stored and consumed evenly throughout the year. This in itself suggests an environmentally determined strategy as the need for food management can be used to explain the use of food storage. The reasons for the variation in diet, could then be argued to have a social origin, if the quantities of the food produced in the lower Ica Valley were insufficient.

The social argument can take one of two courses. Firstly, these variations may have been due to food sharing among members of an *ayllu*, the kin-based network that had settled along the vertical archipelago. This system aimed to ensure that all members had adequate supplies of resources through the exploitation of a variety of production zones and regular reciprocity when needed. The use of the *ayllu* system could be used to argue that a social solution was used in response to a biologically or environmentally driven need for different foods. Redistribution through the *ayllu* could be used to explain either trend two, where food is redistributed routinely at regular times in the year, or trend three, where food is distributed as and when it is needed. However, some coastal systems are thought to have been based on a horizontal archipelago rather than a vertical one for food acquisition (Rostworowski 2004; Shimada 1982), although the two archipelagos have been proposed to work in conjunction in other coastal areas (Tomczak 2003). The range of resources available in a horizontal system is unlikely to have provided a wider isotopic range than would have been available naturally in the lower Ica Valley. Moreover, the whole of the south coast has been argued as being affected by a downturn in environmental conditions during the Middle Horizon (Eitel *et al.* 2005), thus limiting any possibility of new resource acquisition along a horizontal vector.

Movement of people through the landscape connected to trade or exchange may be another possible explanation for the observed hair trends. Rather than food being distributed by the *ayllu* system, people may have travelled with llama caravans and thus would have been exposed to and consumed isotopically varied diets. This type of movement could have occurred in either a regular or irregular fashion and thus be used to explain either trend 2 or 3 or both.

The second line of argument would centre around the presence of the Wari empire on the south coast and the need to create social distinctions between, for example, highland elites and coastal commoners, through food. Maize has long been regarded as a high status crop and therefore is hypothesised to have been consumed in greater quantities by elites than commoners (Hastorf 1991), although the isotopic evidence for the Middle Horizon has not

always supported this (Kellner and Schoeninger 2008). Maize was the mainstay of the diet at the site of Conchopata, located very close to the Wari capital (Finucane 2007; Finucane *et al.* 2006). Thus maize and its consumption may very well have been part of the Wari heartland social identity. If the model of resident elites in coastal sites is correct then it may be that they were preferentially consuming maize in order to assert their social status (van Buren 1996). Bearing in mind the archaeobotanical data from this period (Beresford-Jones *et al.* 2011b), imported highland maize would have created the observed isotopic effect (increased $\delta^{13}C$) and given the cost of transporting it, it would have been suitably high status. Why the maize was only consumed during certain times of the year is harder to explain. It may be a reflection of a single harvesting event so that the elites were eating seasonally, consuming maize as soon as it was harvested, although maize can be dried or ground into flour and stored. *Chicha*, a maize product that has been linked to high status consumption (Hastorf 1991; Hastorf and Johannessen 1993; Valdez 2006), could also have been made and stored, and would cause a signal like that seen in trend one. The $\delta^{13}C$ values of the trend 2 individuals do not suggest a diet predominantly comprised of C_4 foods and there are other individuals with higher $\delta^{13}C$ bone values (who are not represented in the seasonal data). On the face of it the trend 2 individuals then do not necessarily have the isotopic values of high status individuals compared to the whole population and therefore this second argument is less robust.

Relocation

The isotopic signals that vary in an irregular manner may have been due to the relocation of an individual from one location to another either permanently or semi-permanently. This could have been for either economic or social reasons, e.g. as labour, marriage alliance or political resettlement. Individual 101 shows the best isotopic evidence for a permanent move of this kind, shortly (c.7 months) before death. This individual was an adult female aged 26-35 years of age. With no other contextual information (e.g. detailed pathology, burial custom etc) it is difficult to draw any further conclusions about this individual.

Feasting

A final explanation would be dietary change linked to ritual feasts. One mechanism used to enforce state control is the hospitality of the state as remuneration for labour or tribute payments, akin to the *ayllu* reciprocity system. *Chicha* (maize beer) was used in Inca ritual feasts postulated to be provided by the state to fund state enterprises through reciprocity, and

the use of *chicha* in this way has also been suggested for the Wari (see for example Godelier 1977; Goldstein 2003; Hastorf and Johannessen 1993; Isbell 1988; Valdez 2006). However, the periods of elevated carbon isotope values in the individuals last several months and therefore the 'feasting' would have had to be a prolonged event. This is possible, for example when major building works are undertaken. However, the foods used for feasts are also not necessarily different to the everyday foods, only the circumstances in which they are consumed (Douglas 1972) and therefore a shift in isotope values would not be expected. The repeated shifts seen in the hair data do not support this idea as the frequent labour exchange would not have left time for these individuals to carry out their normal daily activities, e.g. production of crops, which underpins this system as the state could not have continually supported the basic needs of the population when they were not enlisted for state projects.

Thus, the most likely explanation for the trend 2 and 3 fluctuating isotopic signals is either the consumption of a highly seasonal diet, or the exploitation of vertically positioned resources through either *ayllu* reciprocity or human movement connected with trade. The regularity of the isotopic change in trend 2, is perhaps more suggestive of a highly seasonal diet, either involving an outside contribution (i.e. *ayllu* input), whereas the irregular signal would reflect a movement across the landscape punctuated by longer spells in certain areas, most likely for trade or exchange purposes. The first trend, a constant isotopic signal along the hair length, can be best explained by the regulation of food, either through careful management and storage or an external source of food regularly added to the diet.

Osteology and Pathology

The majority of individuals (31/38) from the two cemeteries had some type of skeletal pathology. The most common was dental pathology (90% of individuals affected), with carious lesions and ante-mortem tooth loss rife. Four individuals had cribra orbitalia, three of whom were juvenile. Their low $\delta^{13}C$ values compared to the rest of the population mirror the trend seen more generally with the juvenile population (see bone data above). There was also one incident each of cranial deformation, cranial trauma and maxillary sinusitis (labelled as 'other' on the graph). There is no obvious division between the individuals with pathologies and those without seen in the bone data (Figure 8.31).

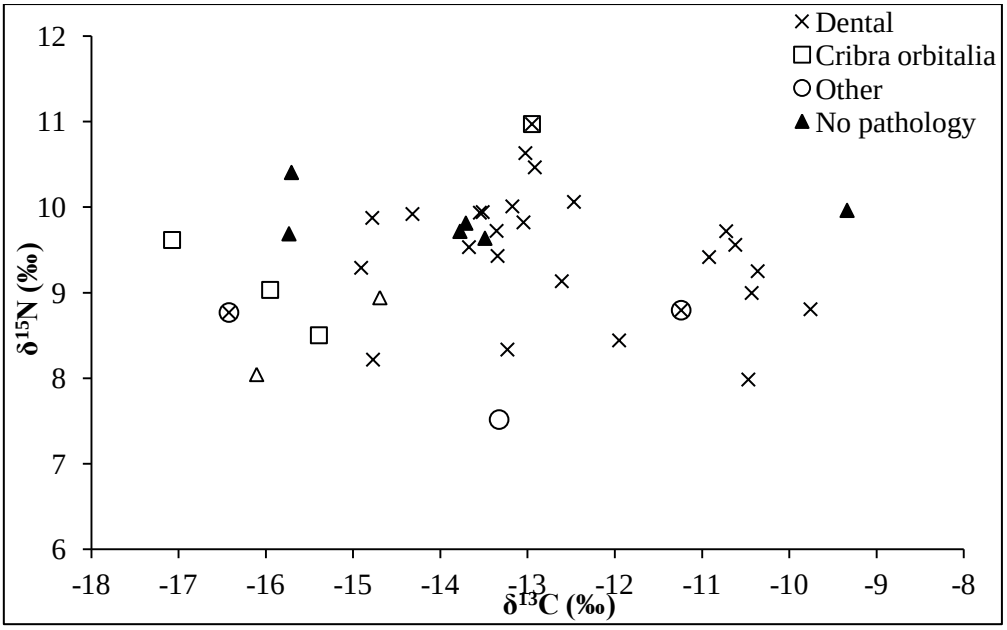

Figure 8.31 Isotope values plotted according to pathologies observed on the skeletal remains. The open triangle represent the two individuals for whom hair data has been used. All other data are derived from bone values. Overlapping symbols are used in cases where an individual has more than one pathology.

Increases in nitrogen isotope values in hair samples have been shown to be useful in identifying physiologically stressed individuals (Fuller *et al.* 2004; Fuller *et al.* 2005; Mekota *et al.* 2006). Four individuals for whom segmental hair data are available show an increase in $\delta^{15}N$ values in the proximal segments of hair (Figure 8.32).

All of these individuals suffered from poor dental health, namely abscesses, carious lesions and ante-mortem tooth loss. All were adults, Individuals 81 and 27 were female and 24 and 94 males. The isotopic increases seen in the proximal ends range from 1.1‰ to 2.7‰ and occur of a period ranging from 5 to 10 months. For the females the length of hair is less than 12cm and therefore it is unknown if what is recorded here is part of a seasonal cycle. For the two males the nitrogen isotopic rise is uncharacteristic given the pattern along the rest of the length of hair. In the two males there is a slight decrease in $\delta^{15}N$ values in the month prior to death.

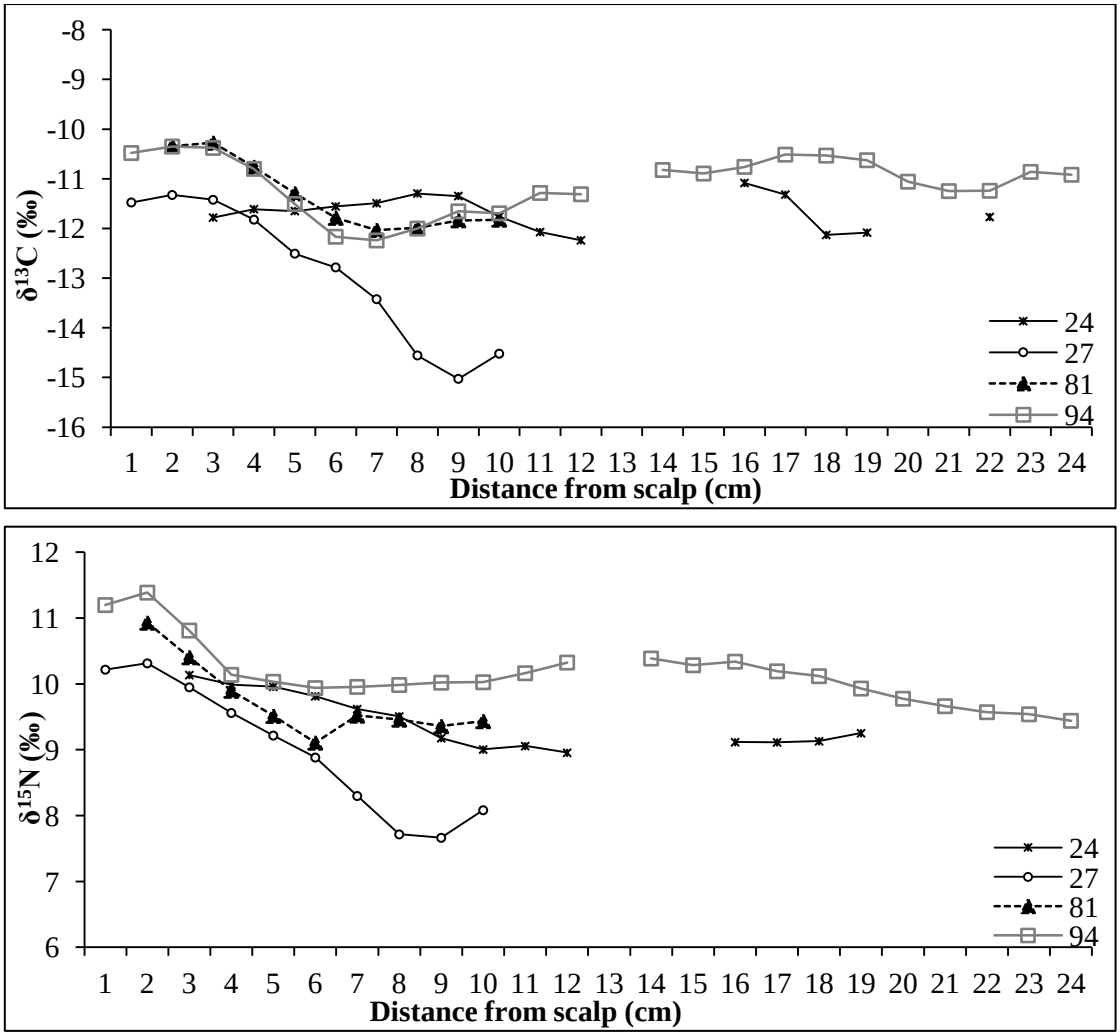

Figure 8.32 Carbon (top) and nitrogen (bottom) isotope data from segmented hair samples for those individuals who show a rise in nitrogen values in the proximal end of the hair shaft.

The expected change in $\delta^{13}C$ with physiological stress is not clearly known, with either no change or a decrease being reported in observational studies (Fuller *et al.* 2004; Fuller *et al.* 2005; Hobson *et al.* 1993; Mekota *et al.* 2006). For Individuals 27 and 94 there is a strong correlation between the carbon and nitrogen isotope values (r_{27}= .98, p<.01 and r_{94}= .46, p<.05). This would lend support to the hypothesis that these changes were due to dietary factors as opposed to physiological stress. This hypothesis is also partially supported in the cases of Individuals 24 and 81 who were estimated to be older individuals (>36 years) and therefore old age is an alternative and reasonable explanation for their death. Of course, it does not discount the possibility that they were stressed at the time of death. For Individual 24 the short hair length makes it difficult to strongly conclude physiological stress. For

Individual 81 the increase in $\delta^{15}N$ is very gradual over a 10 month period and the missing samples in the distal half of the hair (due to poor results) make it difficult to accurately assess the isotopic pattern in the hair prior to the $\delta^{15}N$ rise.

In conclusion, there is no strong evidence that suggests the isotopic values of any individuals were affected by physiological stress immediately prior to death, although it is clear from skeletal observations that the population was largely affected by poor health in some form.

Life Histories

In Chapter 7 it was concluded based on the population level data that there was an isotopic change between infancy and adulthood in both carbon and nitrogen for the Middle Horizon period. This agrees with what has been observed in the data from the individual tissues and the statistical tests conducted. There is a clear difference between the diet of juveniles and adults in the tissues with slow turnover but also a difference between individuals within the tooth data, which records the diet during childhood of each individual.

Therefore there is evidence here for a differentiated society in terms of diet. Dietary differences are marked from childhood and continue into adulthood (according to the clustering of bone and tooth data) but the diet between these two phases in the case of carbon is not necessarily consistent in the same individual. Looking at the difference in isotope values between bone and teeth by tooth cluster, two things become apparent (Figure 8.33). Firstly, there is no relationship between childhood cluster for diet and any tendency to change diet in the adult years, i.e. neither group transformed their diet in a certain way. Secondly, the majority of individuals have a small difference in both carbon and nitrogen isotopes between the times represented by the different tissue formations. As with the segmental hair data only a difference above 2.5‰ is considered significant enough to mean any dietary change above natural variation. There are two individuals who plot near 2.5‰ on the carbon axis, suggestive of a significant change in diet between infancy and adulthood (circled on Figure 8.33).

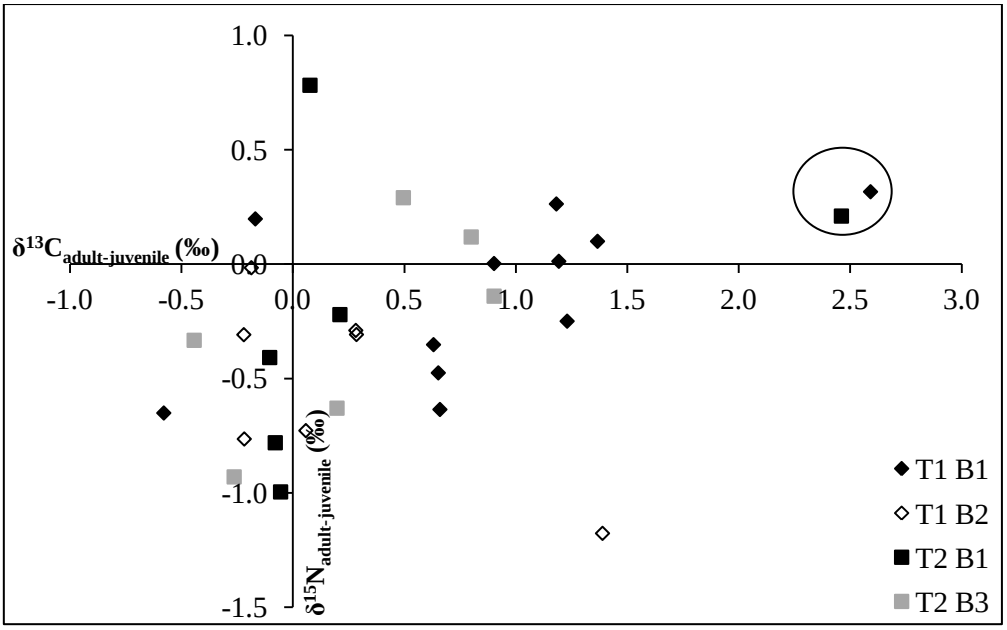

Figure 8.33 Bone-tooth isotopic offsets for the Middle Horizon individuals who had both tissues analysed. The shape of the symbol defines the clusters according to the PCA analysis of tooth data and the colour indicates the cluster according to the bone PCA analysis. The circle indicates the two individuals who show an abnormally high variation in the carbon offset.

These are Individuals 24 and 26. Both are adults over the age of 46 years and from Cemetery 398. Individual 24 is a probable male with a $\delta^{13}C_{bone\text{-}tooth}$ value of 2.6‰. Individual 26 is a female with an offset of 2.5‰. Both individuals were identified as having a constant diet along the length of the segmented hair sample analysed (trend one). The teeth analysed from the individuals were both from the maxillary dentition and were the right first molar for Individual 24 and left second molar for Individual 26. In Chapter 4 the formation times of these teeth were given as 2.5-10 years of age and 6-15 years of age respectively. The signal recorded is highly unlikely to be affected by any breast feeding signal.

As well as a difference between the bone and tooth values, there is also a difference between the bone and hair values for these individuals (Figure 8.34). For Individual 24 it is a substantial difference in carbon isotopes. The difference between tooth and bone values is practically identical to that between bone and hair (2.6‰ and 2.4‰ respectively). For Individual 26 the difference in the bone and hair data is in the nitrogen isotope, although at a magnitude of 1.3‰ this could be due to natural isotopic variation in the food chain.

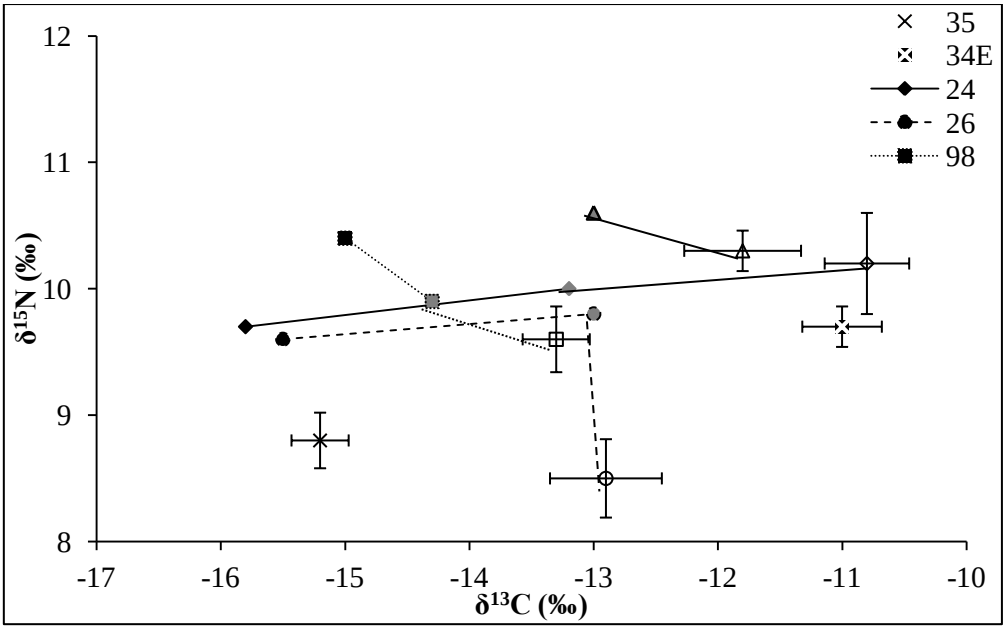

Figure 8.34 Isotopic values of multiple tissue samples from individuals with hair trend 1. The closed black symbols are the tooth data, closed grey represent the bone data, open symbols represent hair data. For Individuals 35 and 34 only hair data are available. Hair values have been made comparable to the collagen by adjusting the values using Crowley et al.*'s (2010) bone-hair offset. The mean segmented hair value has been plotted and the error bars represent one standard deviation away from the mean.*

There are two possible explanations for the isotope patterns in these two individuals:

1) During childhood they were resident in a different area, likely to be a higher altitude where the carbon isotopic signature of the background ecology was more negative. Sometime after the teeth used for analysis were formed these individuals migrated to the lower Ica Valley were they resided for a length of time substantial enough for it to be reflected in their bone collagen. The bone compared to the hair values for carbon isotopes in Individual 26 shows good agreement whereas Individual 24 does not (see Figure 8.34). The bone value of Individual 24 lies midway between that of the tooth and hair, which suggests that the bone isotope value partially represents the childhood place of residence and partly the lower Ica Valley diet. The half-life of cranial bone is given by Rummel and colleagues (2007) as 35 years. Therefore approximately 35 years prior to death this individual moved location. Given that they have been aged 46 years plus, this puts the earliest migration age at 11 years - one year after the molar formed. For Individual 26 the migration would have occurred much earlier before death as the bone isotopic signal is close to the hair value and therefore the

bone would have been completely turned over since the migration. The latest the tooth could have formed is 15 years. This would put the individual at at least 65 years old at death given the turnover rates given by Rummel *et al.* (2007) if they migrated at the age of 15 years old. This of course all rests on the assumption that the isotopic values in the hair represent the average diet consumed since the migration occurred.

2) It has been demonstrated that there is variability amongst the diets of the adult populations over the course of at least 12 months through the segmental analysis of hair and through bulk analyses of tissues. It has also been shown that there are dietary differences between adults and juveniles. The second possible explanation is that in adulthood new foods, enriched in $\delta^{13}C$ became a staple food in the diet of these individuals. It is evident that the new food would have been a staple through the change in bone isotope values and the constant trend in the carbon isotopes of the segmented hair for both individuals. The timing of the introduction of the new food would be the same as those postulated for the migration events in the first scenario.

This restriction and introduction of a certain food have implications for how these coastal Middle Horizon individuals are interpreted. Firstly, can these two individuals be used to characterise all individuals with constant diet signals in the segments hair values? This is in part difficult to answer. Data from tooth, bone and hair are only available for one other individual - Individual 98, an adult male, who showed a constant diet along the hair length. The difference in carbon isotope value between the tooth and bone is only 0.7‰ and bone and hair is 1.0‰. Using the 2.5‰ criteria discussed earlier this does not suggest a significant dietary change. Similar patterns are seen for Individual 25 for whom there is only bone and hair data. Hair data are only available for Individuals 34 and 35. The $\delta^{13}C$ value of Individual 34 is similar to that of Individuals 24 and 25, whereas Individual 35 is more negative and closer in value to the bone samples analysed. Individuals 34 and 35 are also intriguing because the samples originated from hair pieces or wigs rather than cranial samples and so no contextual information is available. Little is known about the role of hair pieces in the Middle Horizon and the likely origin of those samples. From the available data, it appears that Individuals 24 and 26 are unique cases of significant dietary change over the duration of a lifetime.

Both the first or second explanation given above can be taken as evidence for an elite or possibly highlander presence on the coast. The restriction of food resources suggests that

social identities were transformed at a certain life stage. As the $\delta^{13}C$ values become more enriched later in life, reaching a maximum of -14‰ to -12‰, and nitrogen either decreases or remains the same, a C_4 food resource would be responsible for this shift. Maize is well accepted as a high status food but C_4 are also more generally abundant on the coast than in the highlands (Cadwallader *et al.* 2012). Regular consumption of a C_4 plant would result in the constant diet seen in the hair, although C_3 foods were also consumed. One flaw in the highlander migrant theory is that maize is known to have been a key resource and grew well in the highlands during the Middle Horizon. If these were elites who originated from the highlands then their original diet is likely to have included maize rather than not, even as juveniles (Finucane *et al.* 2006). There is also a more C_4 group seen in the bone data, which is suggestive of high maize consumers, and thus better candidates for highlander elites. What is being observed with the these two individuals, then, may be a local custom do with restricting certain foods from children.

Summary

The analyses conducted on the Middle Horizon material suggest that the diet consumed by the population was of terrestrial origin and included both C_3 and C_4 resources in varying degree. Different groupings of individuals have been identified according to the different tissues used. The bone, tooth, skin and averaged hair data all suggest similar groupings, with two different adult groups and one juvenile group. The segmented hair data suggest three adult groups, which were not visible in the other tissues or averaged hair data. Additionally a significant dietary life history change has been identified for two individuals. As the Middle Horizon data are somewhat complicated by the complexity of groups in the different tissues, further analysis shall be conducted on this dataset in Section 8.6.

8.5 Late Intermediate Period

8.5.1 Fauna

Ten camelids were sampled for bone from Cemetery 1003, three of whom were also sampled for wool and one for a tooth. A bone sample from a dog was also taken. All of the samples produced acceptable results. The camelid bone samples have a mean $\delta^{13}C$ of -16.2 ±2.4‰ with a range of -19.1‰ to -12.4‰. The mean $\delta^{15}N$ of the camelid bone samples is 6.7 ±0.9‰ with a range of 4.7‰ to 8.3‰. For wool, the $\delta^{13}C$ mean is -19.7 ±0.9‰, with a range of -20.3‰ to -18.7‰. The mean $\delta^{15}N$ value is 7.9 ±0.9‰, with a range of 7.0‰ to 8.7‰. The

isotopic value of the camelid tooth is -15.9‰ for carbon and 8.7‰ for nitrogen, which fits well with the bone data in terms of carbon isotope but less so with nitrogen (Figure 8.35). This tooth is an M1, which erupts at the age of 6-9 months in llamas (Wheeler 1982). Formation will occur prior to this and therefore is likely to incorporate a pre-weaning isotopic signal. The dog bone value is -10.7‰ for carbon and 10.1‰ for nitrogen.

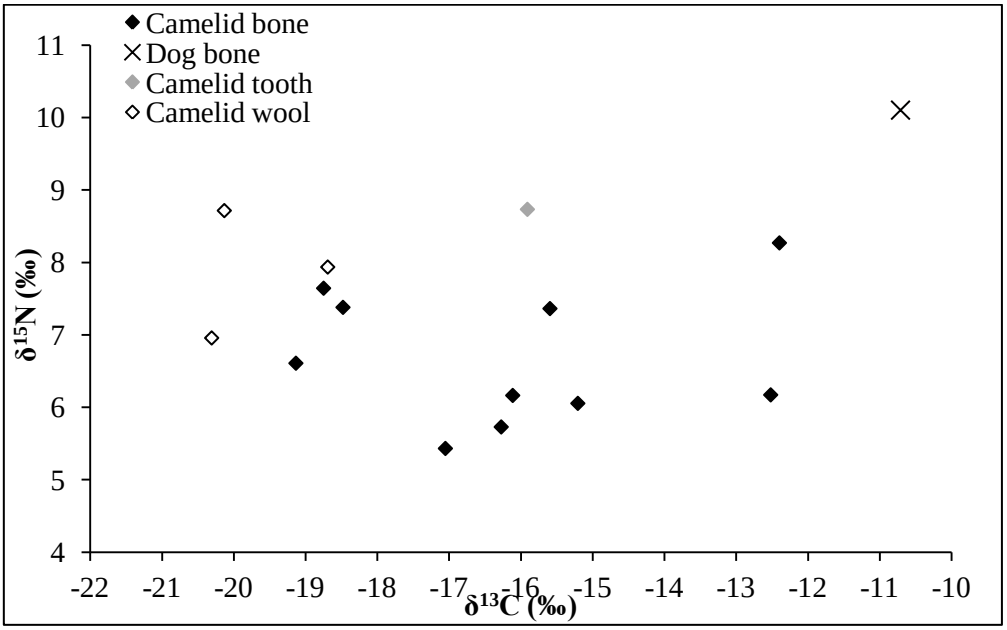

Figure 8.35 Faunal isotopic data from the Late Intermediate Period cemetery.

These camelid values are similar to those found in all three of the previous cultural groups and thus can be viewed as typical for terrestrial herbivores. The range of carbon isotopes encompasses both C_3 and C_4 plant based diets. The one sample from the dog has an elevated nitrogen isotope value compared to the herbivores, as expected for a carnivore. The carbon isotope value indicates a C_4 basis to the diet, which could have been derived from either wild grasses or maize.

8.5.2 Humans

Samples were taken from all four tissues types. All bone (n=26) and skin (n=10) samples produced acceptable results; one hair sample out of twenty was excluded completely due to a poor C/N ratio. Of the 19 acceptable hair samples, two were bulk sampled and 17 cut into 1cm segments. Forty out of 323 of these segments did not produce acceptable results and

were spread amongst the samples. Eighteen out of 21 tooth samples produced acceptable results with the three others either being unsuitable for analysis or too poorly preserved to extract dentine.

A complete set of the four tissues samples was taken for three individuals, 12 individuals had three tissues sampled, 11 individuals had two tissues sampled, and only one individual had just one tissue sampled.

Overall Population Diet

Bone

For the population as a whole the bone isotopic values were not normally distributed for carbon but were for nitrogen. The median carbon value was -10.3‰, with 1st and 3rd quartiles of -11.2‰ and -9.8‰ respectively. The carbon isotopes ranged from -15.3‰ to -8.8‰, including one very clear outlier (-15.3‰, see Figure 8.36). For nitrogen isotopes the median was 9.7‰ with values of 9.2‰ and 10.6‰ for the first and third quartiles. The overall range was between 8.3‰ and 12.3‰, with a mean of 9.7 ±1.0‰.

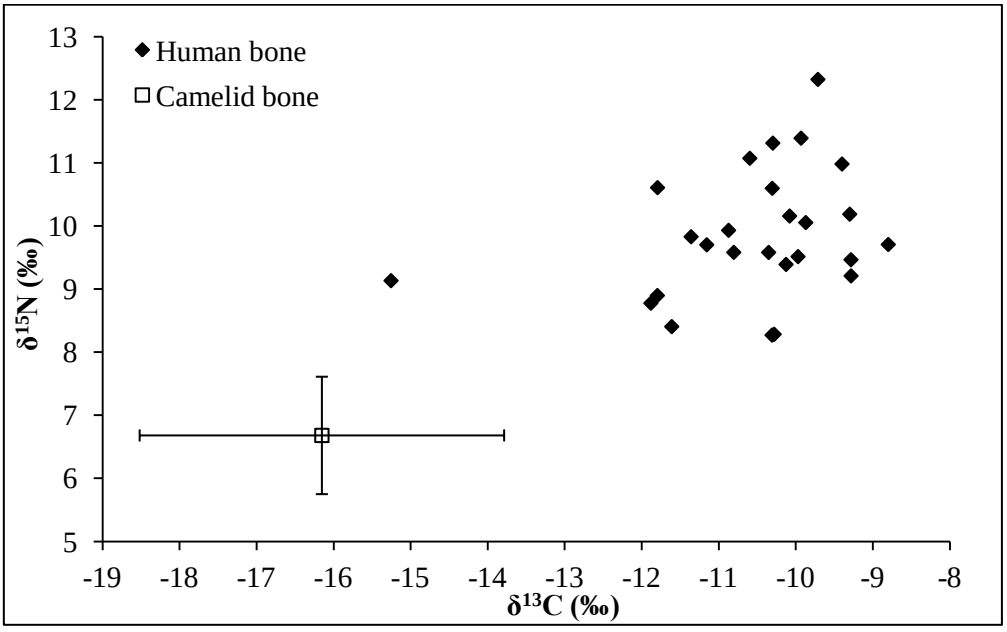

Figure 8.36 Human bone isotopic data and the faunal bone mean. Error bars represent one standard deviation.

Statistical tests applied to the data showed no significant difference between any sub-sets of the population with respect to age or sex in either carbon or nitrogen isotopes and therefore the population can be considered as homogenous in terms of diet, except for the obvious outlier. Applying PCA analysis showed that there is no one variable that strongly accounts for the variation in the data.

The isotopic signal observed in the population suggests a C_4 terrestrial origin for the food of the majority of the population. The camelids had a large spread of values, which makes it difficult to assess whether the signal in the humans is as a result of direct or indirect consumption. The majority of the population plot between 3‰ and 5‰ higher than the camelid mean $\delta^{15}N$ value, suggesting they all consumed terrestrial meat (O'Connell *et al.* 2012). The individuals with the highest nitrogen values may have been consuming some marine foods but the isotopic exact offset between the trophic levels is uncertain (see discussion in Section 4.3.1). No infants plot amongst the highest $\delta^{15}N$ values and so a breastfeeding signal can be ruled out. The variation in human nitrogen isotopes could be explained instead by a varying level of terrestrial meat consumption between the individuals, i.e. infrequent versus frequent meat eaters (O'Connell and Hedges 1999a). The outlier with the low $\delta^{13}C$ value would have had a mixed C_3/C_4 terrestrial diet.

Tooth

The tooth data show similar overall results to bone. The tooth data are normally distributed for both isotopes. The mean $\delta^{13}C$ value is -10.9 ±1.4‰ with a range between -14.6‰ and -9.2‰. The mean $\delta^{15}N$ value is 9.8 ±0.8‰ with a range between 8.4‰ and 11.4‰. As with bone the majority of the individuals plot between -12‰ and -9‰ for carbon and 9‰ to 12‰ for nitrogen isotopic values (Figure 8.37).

Again there is no statistical difference between ages or sexes or tooth types analysed. The dietary interpretations are the same as those for bone but with two individuals having a mixed C_3/C_4 diet. The individual with the lowest $\delta^{13}C$ value is the same for both the bone and tooth data.

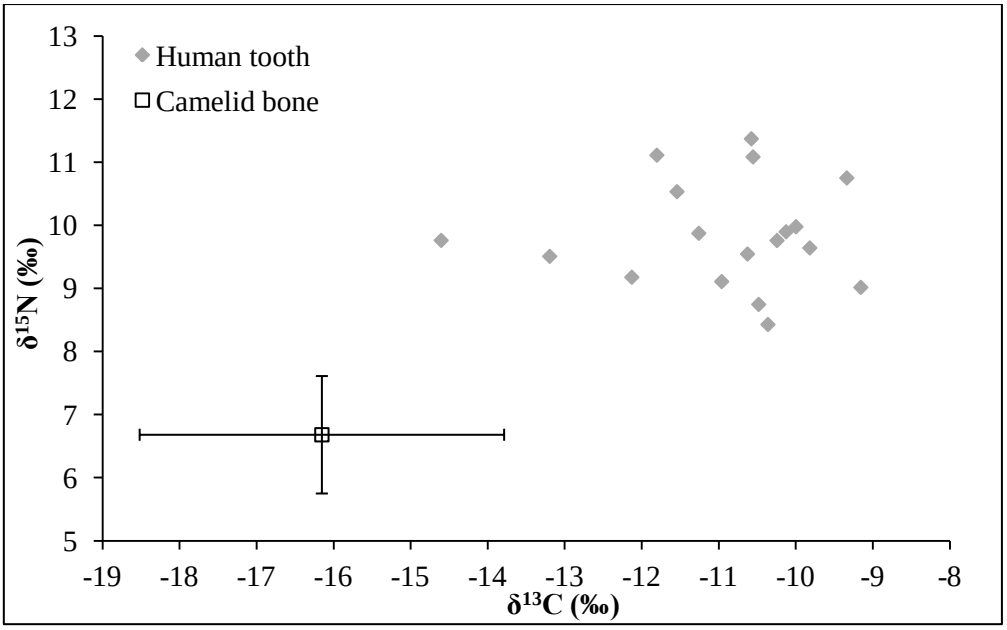

Figure 8.37 Human tooth isotopic data. The camelid mean bone value is also given. Error bars represent one standard deviation.

Hair

The hair data are normally distributed. The individual means for the hair samples analysed are similar to those observed for both bone and teeth. The carbon isotopes ranges from -13.8‰ to -9.1‰ with a mean of -11.4 ±1.4‰. The $\delta^{15}N$ values range from 7.2‰ to 13.4‰, with a mean of 9.3 ±1.4‰ (Figure 8.38). There is no statistical difference between any age or sex groups.

The hair values plot slightly lower in both carbon and nitrogen than the bone and tooth data. This is to be expected as keratin should be less enriched than collagen as discussed earlier in Section 7.2.3.

Skin

The skin data once again conform to the general patterns observed in the other tissues (Figure 8.39), with the exception of the nitrogen isotope values, which have been discussed in Chapter 7. The data are normally distributed, with a $\delta^{13}C$ mean of -10.2 ±1.1‰ and a range of -11.4‰ to -7.8‰. The $\delta^{15}N$ mean is 12.7 ±1.3‰, with a range between 10.8‰ and 14.9‰. Whilst these values are much higher than the other tissues, the spread of the nitrogen isotopic data is virtually equal to that of bone and smaller than the hair data. There are not enough

individuals to be able to test the data for differences in age or sex. The carbon isotope results fall into the -12‰ to -9‰ range seen for the majority of individuals in the other tissue types.

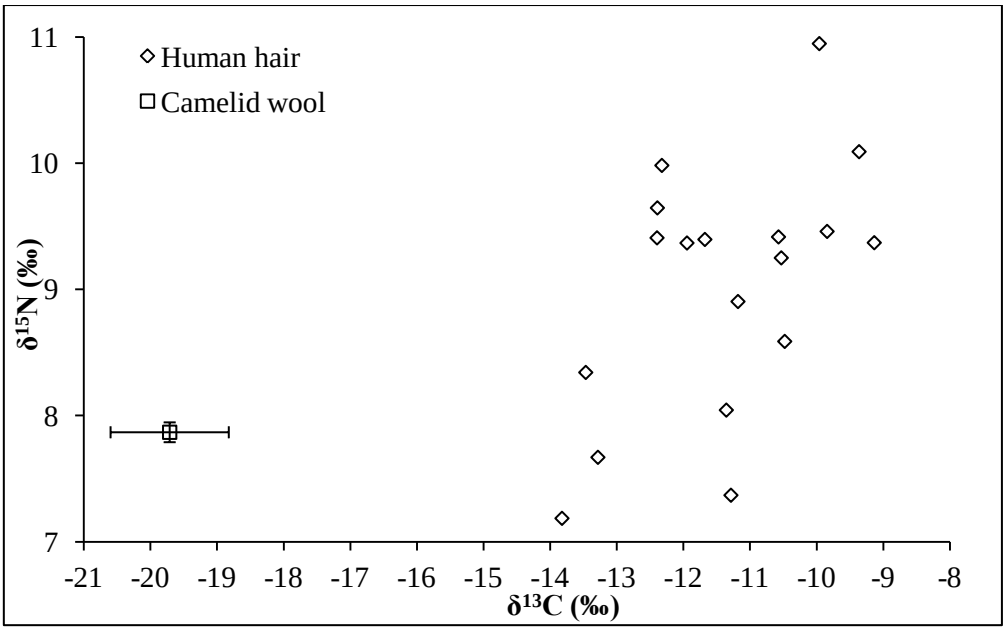

Figure 8.38 Human hair isotopic data and mean camelid wool value (n=3). The error bars represent one standard deviation.

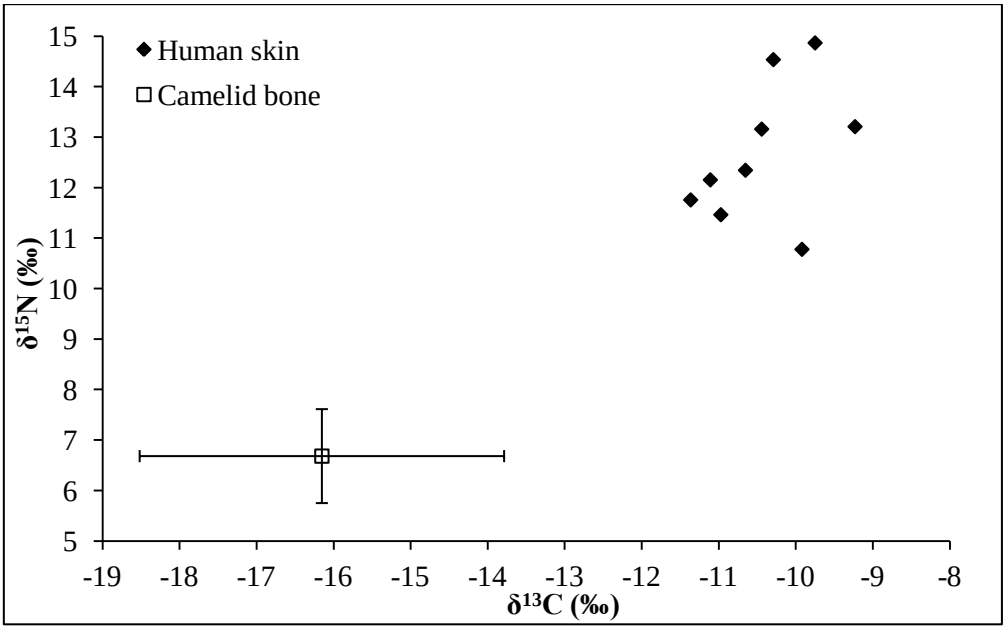

Figure 8.39 Human skin isotopic values and the mean camelid bone value. The error bars represent one standard deviation from the mean.

In summary, from the bulk tissue values it is clear that there was a narrow isotopic range of dietary inputs, which were C_4 based. An argument can be made for consumption of marine resources by a small number of individuals but this is not certain and they are not separated out by statistical analyses.

Seasonal Hair

Segmented analysis was carried out on hair samples from 17 individuals. The length of the hairs ranged from 6 to 44cm, with the majority between 11 and 20cm in length (n=8). Eleven individuals had hair lengths that represented at least one years worth of growth. The mean $\delta^{13}C$ value of the individual means is -11.6 ±1.3‰, with a range of -13.8‰ to -9.1‰. For $\delta^{15}N$ the mean is 9.2 ±1.5‰, with a range between 7.2‰ and 13.4‰. The isotopic variation along the length of an individual's hair ranged from 0.5‰ to 2.8‰ for carbon and 0.5‰ to 3.0‰ for nitrogen. The mean isotopic variation along the hair shaft for all individuals was 1.6‰ for both carbon and nitrogen.

Unlike with the Middle Horizon data, the length of hair does not seem to have an impact on the variation seen in the hair but the carbon isotopic range and mean value are significantly linked (Figure 8.40). This is evident in both correlation of the two variables and through a stepwise linear regression of the data.

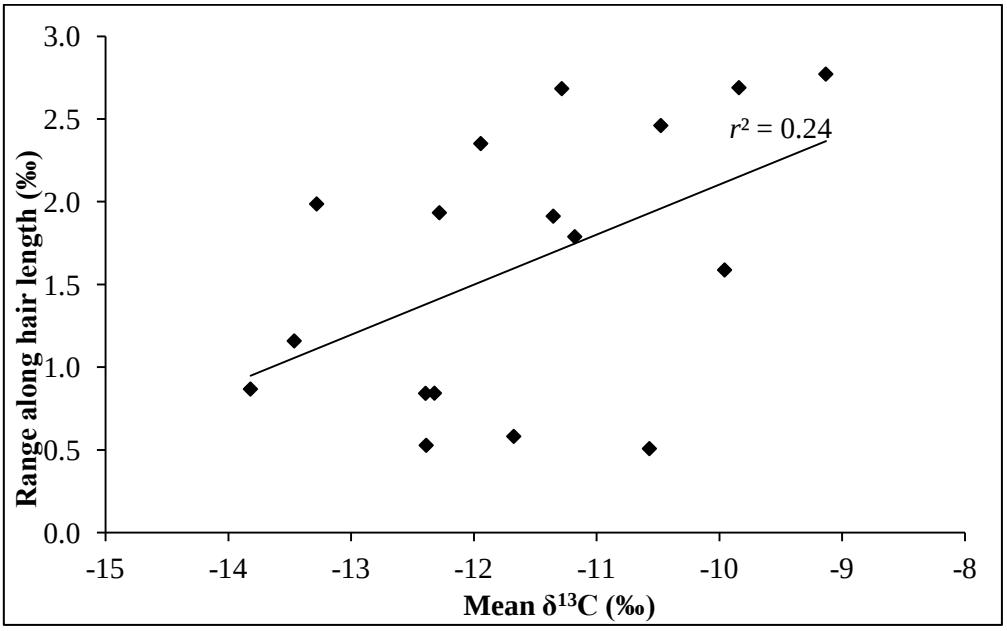

Figure 8.40 Correlation between the mean carbon isotope value and the range in carbon isotopes along the length of the hair for each individual with segmented hair data in the Late Intermediate Period.

From this it appears that the individuals who consumed a predominantly C_4 diet had more variation in dietary inputs over a year than those who had a more mixed C_3/C_4 diet. This holds true even when only the individuals with more than 12cm of hair are analysed and in fact the relationship becomes more significant (r= .72, p<.01). Excluding the individuals with less than 12cm of hair ensures that the full variation caused by any seasonal changes is accounted for. Although the length of the hair was not shown to be important in the stepwise linear regression this measure is precautionary. The strengthening of the relationship with carbon isotopes when only >12cm hairs are used suggests that the shorter length individuals with higher carbon isotope bulk values do not show the full range in values along the length of the hair (Figure 8.41).

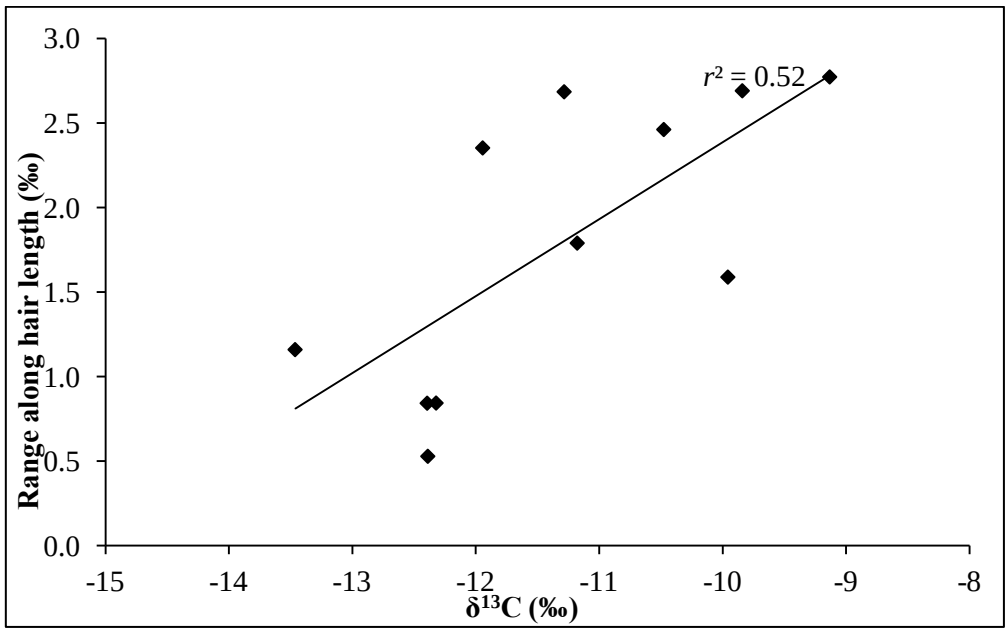

Figure 8.41 Correlation between mean carbon isotope value and the carbon isotope range seen along the length of the hair for those samples with at least 12cm of growth.

Performing cluster analysis on the isotopic ranges of the individuals with hair lengths over 12cm enabled the identification of two groups, which are divided according to their carbon isotope range (Figure 8.42). The first cluster (n=5) all have carbon ranges of less than or equal to 1.6% and a nitrogen isotopic range of less than or equal to 1.4‰. Cluster 2 (n=6) all have ranges greater than or equal to 1.8‰ in carbon and 1.4‰ in nitrogen isotopes. Ten out of the eleven of the individuals with hair longer than 12cm are adults. It was not possible to

identify the age to any extent of the remaining individual as the sample was taken from a loose piece of hair. The other tissues that have been analysed from these ten individuals do not form groups when a cluster analysis is performed on the data.

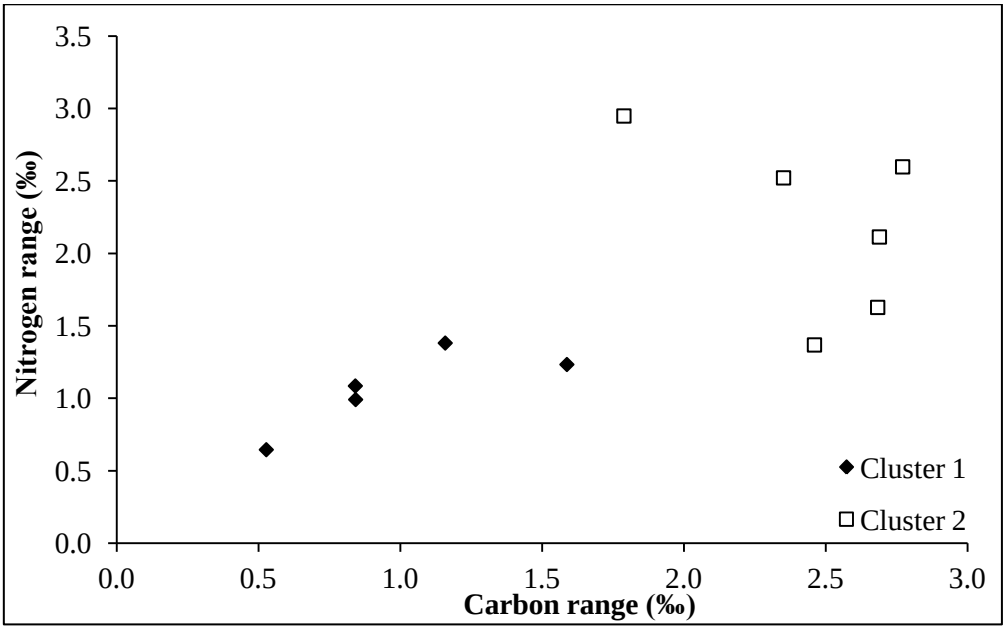

Figure 8.42 Range in carbon and nitrogen isotope values along the length of the hair for samples with more than 12cm growth. The clusters, identified through cluster analysis, separate the data based on the amount of variation.

Trend 1 - Low Variation

The five individuals with low variation do not all show the constant diets expected in this group. Three individuals (39, 28 and 47) have generally very flat lines for carbon and nitrogen isotopes, whereas the other two individuals show greater isotopic variation along the length of the shaft (Figure 8.43). However, the variation is still low when considered in light of the natural isotopic variance of the background ecology. It is interesting to note the isotopic values of these individuals in the context of the whole population. For individual mean $\delta^{13}C$ hair values the majority of the population fell between -12‰ and -9‰, with a mean of -11.4‰. Four of the five individuals here have carbon values which are towards the lower limit of the carbon values (-13.8‰) seen for the whole population (bulk and means of segmented values). For nitrogen these four individuals fit into what was observed for the

majority of the population, plotting between approximately 9‰ and 11‰. The individual with lower $\delta^{13}C$ values also has a lower $\delta^{15}N$ value than most individuals. These individuals have a primarily C_4 diet but with inputs from C_3 sources of terrestrial origin. The one exception is Individual 36 who has both elevated carbon and nitrogen isotopic values suggesting marine consumption as the mainstay of this individual's diet.

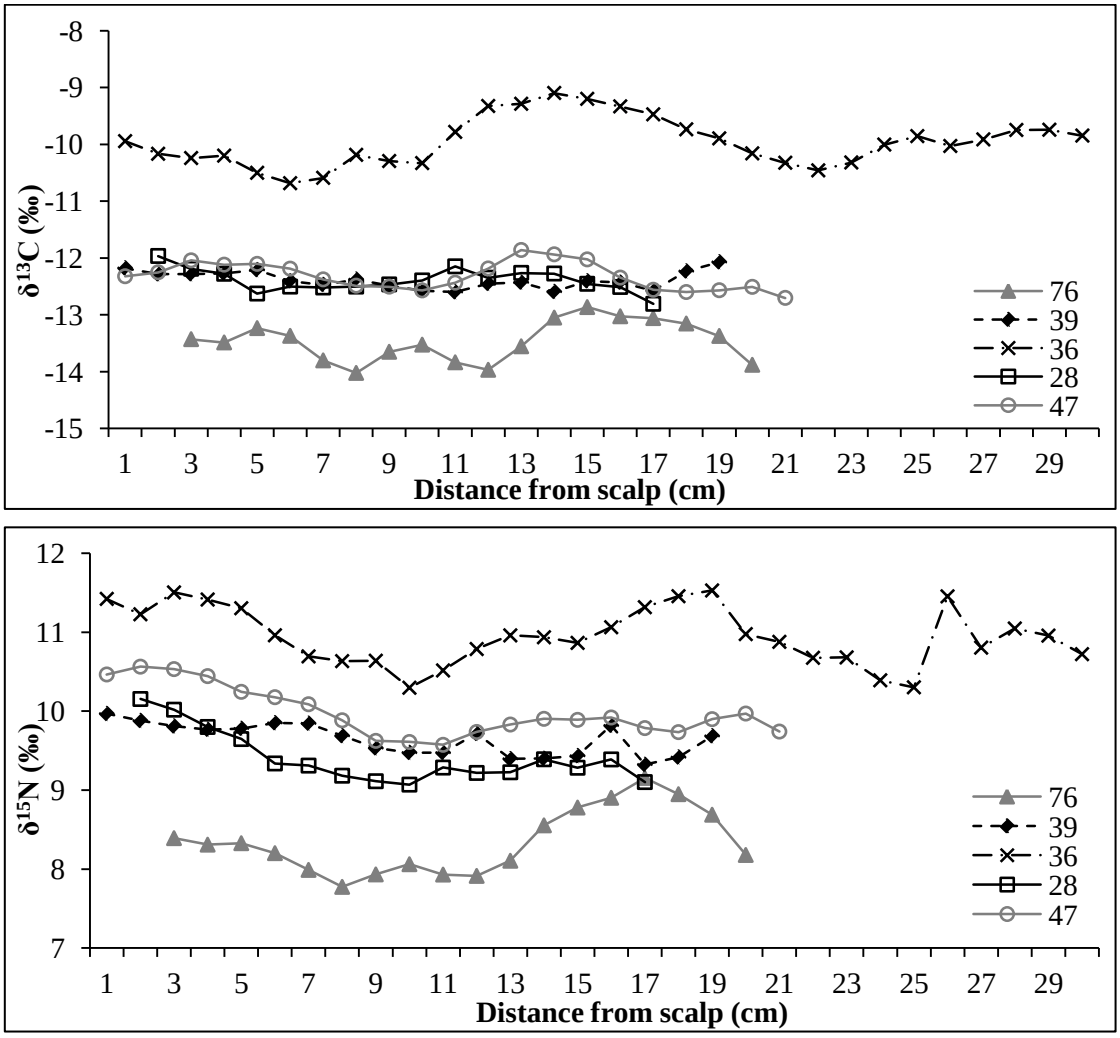

Figure 8.43 Carbon (top) and nitrogen (bottom) isotope data for segmented hair samples that show low variation along the length of the shaft.

High Variation

The individuals who show high variation (n=6) can be separated into two groups based on the shape of the isotopic data when plotted against hair length.

Trend 2 - 'Regular' shifts

Four individuals (three females and one male) fall into this category. The isotope values fluctuate between their maximum and minimum values in a fairly regular way (Figure 8.44). Although these curves are not a classic sinusoidal shape like those observed for the Middle Horizon they do show a fairly even split in terms of number of segments in the peaks and troughs. The carbon and nitrogen isotope results are correlated significantly (r= .45, p<.01). With the exception of the proximal 7cm of Individual 120, all of the $\delta^{13}C$ values fall within the range of the bulk of the population. The carbon isotope peak is at approximately -9.5‰ and the trough is at approximately -12.0‰. This suggests a switch between a fully C_4 based diet and a mixed C_3/C_4 diet. The nitrogen isotope values are not so uniform in their peaks and troughs on the other hand, although the ranges do all fall within a terrestrial signal.

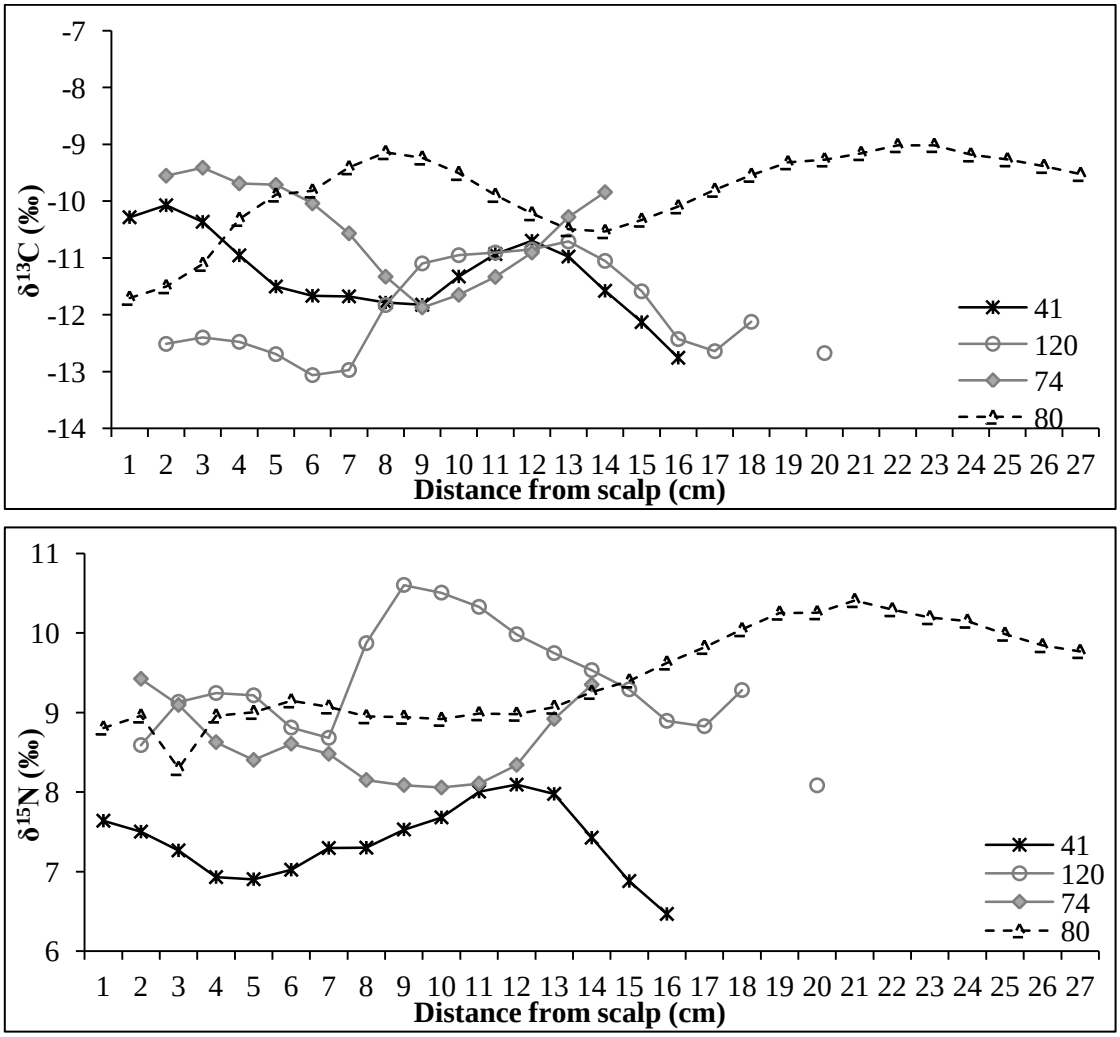

Figure 8.44 Carbon (top) and nitrogen (bottom) isotopic data for segmented hair samples that show high variation along the length of the shaft.

The nitrogen isotope values are in general around the population mean value of 9.3‰. Individuals 41 and 74 fall below the range of the majority of the population (9‰ to 11‰), where as Individuals 120 and 80 plot in this range. None of the individuals have high $\delta^{15}N$ values that indicate significant marine consumption.

As in the Middle Horizon this trend suggests the exploitation of multiple production zones due to the high intra-individual variance. The positive correlation between the carbon and nitrogen isotope values suggests one reason for this fluctuation may be the periodic inclusion of marine resources. Conversely the tandem decrease in carbon and nitrogen resources could be viewed as a periodic incorporation of resources from higher altitudes as these are more likely to be C_3 plants and less water stressed (i.e. have lower $\delta^{15}N$ values).

Trend 3 - Unidirectional shifts

Two individuals have changes in the isotopic values along the length of the hair which suggest a shift from one isotopic input to another (Figure 8.45). For Individual 30 (probable male adult) this shift is quite dramatic. Both the carbon and nitrogen become more negative in the last 8cm of the hair, with a decrease of 2.6‰ and 2.1‰ in carbon and nitrogen isotope values respectively. Before this the isotope values varied over a range of 0.8‰ and 0.6‰ in carbon and nitrogen respectively over a period of six months. For Individual 77 (age and sex unknown) the change in carbon isotopes is much more subtle with an increase occurring after 20cm. The mean value in the distal 25cm of the hair is -11.5 ±0.2‰. The mean value in the proximal 19cm of hair shifts to -10.8 ±0.4‰. This in itself would not normally be counted as a significant shift in isotope values as the difference is low and within natural variation. However, the nitrogen isotope values do vary dramatically along the length of the hair, with a range of 3.0‰. This change is more gradual than that seen in the carbon data although the shift does begin at the same point in time - after 20cm. The carbon and nitrogen isotopes are significantly correlated in these individuals ($\rho = .65$, $p < .01$).

Individual 30 moves from the one of the highest $\delta^{13}C$ values to one close to the population mean and from higher than the population mean $\delta^{15}N$ value to well below it. Individual 77 plots roughly at the population mean for carbon but in nitrogen the values span the values seen for the majority of the population, i.e. between 9‰ and 11‰.

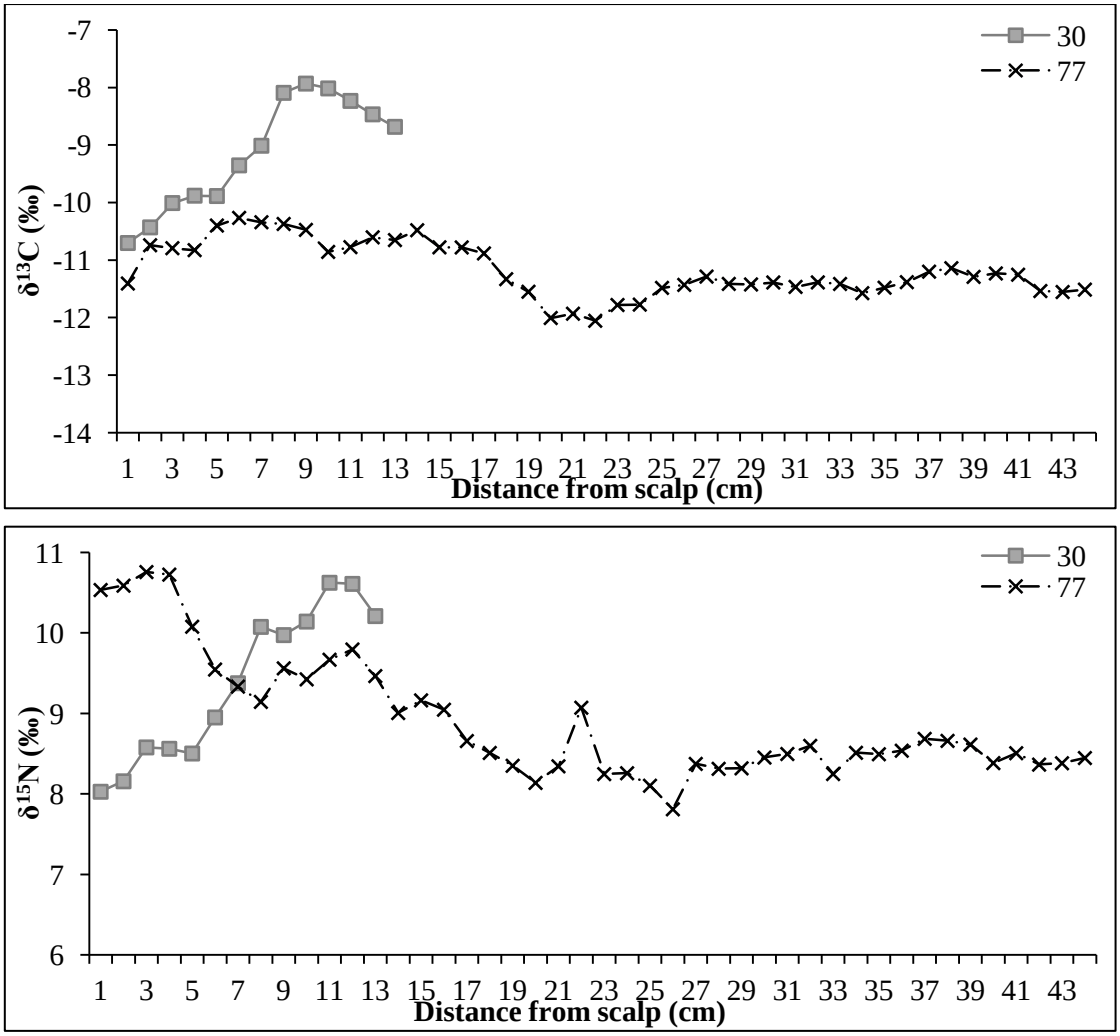

Figure 8.45 Carbon (top) and nitrogen (bottom) isotopic data along the length of segmented hair sample that shows unidirectional change.

For Individual 30, the correlation between the carbon and nitrogen isotopes and the high maximum values for the isotopes suggest a shift from marine inputs to terrestrial ones, which retained a C_4 base. For Individual 77 the opposite is true, albeit the carbon isotopic shift is not so dramatic. This could be due to a lag in carbon isotopic equilibrium which has been observed in modern studies (O'Connell and Hedges 1999a). However, Hedges (2004) has hypothesised that in a terrestrial diet with low protein (e.g. Individual 77 pre-switch), an addition of minor dietary contributions (20-30%) from marine sources will theoretically make little difference to the carbon isotope value. Thus Individual 77 could have increased the marine contribution in their diet around 20 months before death which has been reflected in their nitrogen isotope but to a much smaller extent in their carbon.

Thus there is evidence for a shift from one dietary regime to another, with a significant change in the production zone exploited. Relocation is the most obvious cause of this change, especially given the role of marine foods in both the diet and the Late Intermediate Period economy in neighbouring areas.

Osteology and Pathology

Sixty-one percent (n=28) of the population from this period showed pathological changes on their skeletal remains that would have had some effect on their quality of life. The most commonly observed were dental pathologies (77%). The other pathologies were a few incidences of cranial trauma (n=2), osteoarthritis (n=3) and cribra orbitalia (n=3). Four individuals exhibited two pathologies each. There is no obvious association between the isotopic data and presence of pathology (Figure 8.46).

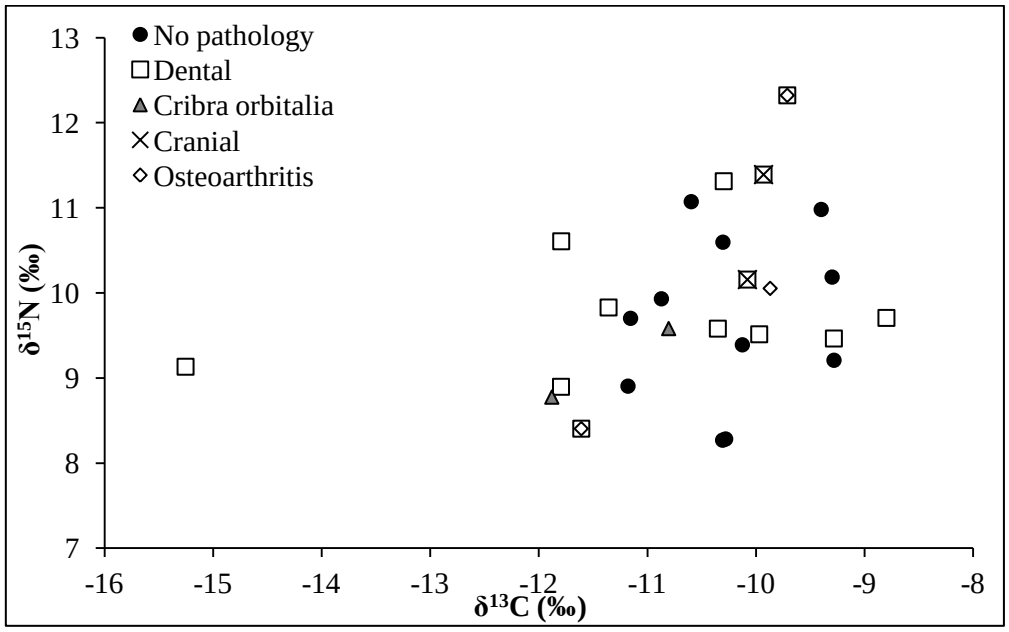

Figure 8.46 Bone isotopic data plotted according to the pathology observed on the skeletal remains. Individuals with more than one pathology observed are represented by overlapping symbols.

Life Histories

Chapter 7 showed the diet to be more or less constant between successive life stages for the whole population. However, taking particular individuals into account this does not always hold true. Between the tooth and bone collagen data there is little variation within the lifetime

of an individual, as can be seen in Figure 8.47. All of the offsets are less than 2‰ for both isotopes with the majority changing less than 1‰. The bone and hair offsets (with the hair value corrected using Crowley *et al.* 2010) show slightly more variation between the two tissues, with three individuals with large enough offsets (>2‰) to warrant further investigation. Individuals 36 and 37 both show a large difference (2.2‰ and 2.9‰ respectively) in nitrogen isotopes, with their hair values enriched compared to the bone. Their carbon values show approximately 1‰ change but not in a uniform direction. For Individual 36 (young adult male) the change suggests an increase of marine foods or more frequent terrestrial meat consumption in the latter part of their life (i.e. hair data). This individual falls into the trend 1 hair group (low variation). Their end $\delta^{15}N$ mean value is 11.8‰ (corrected), which is towards the higher end of the spectrum of values expected for a terrestrial meat consumer. The increase in carbon isotopes, albeit a small one, does support the marine theory.

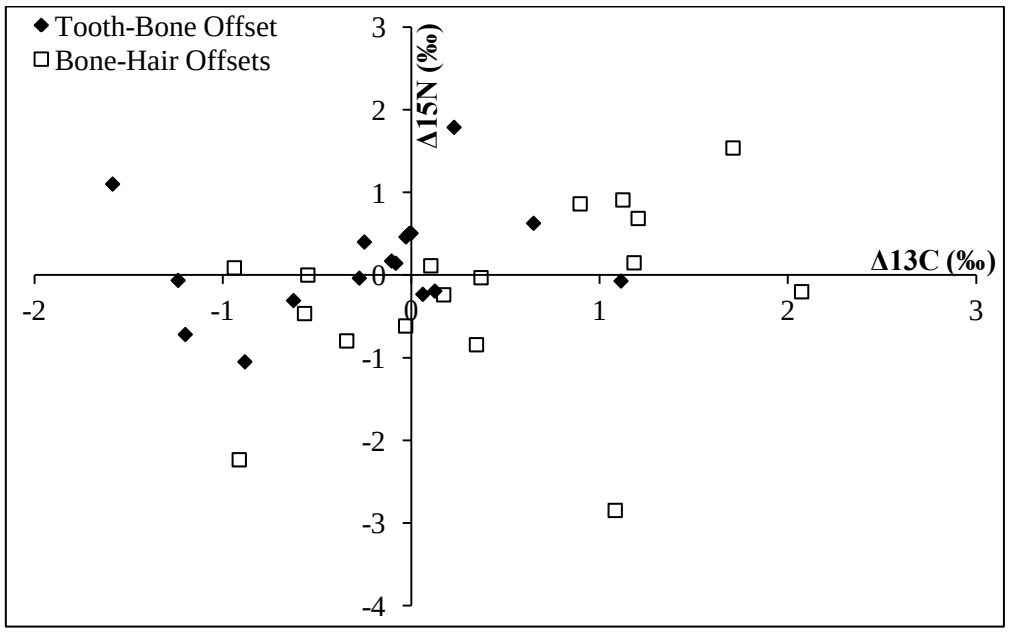

Figure 8.47 Tooth-bone (n=17) and bone-hair (n=17) isotopic offsets for individuals which had multiple tissues analysed. The spread of the data shows that there were no trends that indicate a change in diet between childhood and adulthood, nor between adulthood and the time immediately before death.

For Individual 37 (mature adult male) the carbon isotope value decreases as the nitrogen value increases as one moves from the bone to the hair value. The nitrogen isotopic values for this individual are at a higher level compared to Individual 36, with a hair value of 14.2‰ (corrected). This is much more indicative of a marine based diet. The small change in carbon (-1.1‰) can be explained as natural variation in the isotopic background. This individual then appears to have changed to a marine diet towards the end of their life from a lifetime of terrestrial food consumption.

One individual shows high variation in carbon isotopes (2.1‰) between their bone and hair value but virtually no change in nitrogen (-0.2‰). This individual is a juvenile of unknown age (<18 years). The change only in the carbon suggests a plant based isotopic change, with more C_3 plants consumed in approximately the last year of their life. The change in plant base is supported by the nitrogen isotope values (8.5‰ in hair), which suggest infrequent meat consumption.

In sum there are some shifts over the life time of individuals among different food resources. However, there is a lack of evidence to support population level dietary shifts. The few significant shifts that do occur are seen in the hair data in comparison to the bone data but are not uniform in their direction.

Summary

The Late Intermediate Period population was fairly homogenous in terms of diet but there was some diversity within the population from which we can begin to understand socio-economic practices.

The dietary isotopes show that the individuals ate a C_4 based diet. For some of these individuals, their diet may have had a marine component. The range of carbon isotopes in the camelid samples suggest that the C_4 plants contributed to the diet of the vast majority of the population as the humans are more enriched in $\delta^{13}C$ than the animals. Although there are several wild C_4 plants in the region and the pseudo-cereal kiwicha is also C_4 (Cadwallader *et al.* 2012), there is a strong link with maize consumption in the historical documentary sources as well as a strong presence in the archaeobotany from this period (Conlee 2003). Kiwicha may have well contributed to this signal, in part thanks to its high protein content that would be reflected in the collagen and keratin. However, there is no supporting evidence for this currently, possibly due to the difficulties in identifying it morphologically (Bruno 2006). For some individuals a mixed C_3/C_4 diet is proposed. This could have been achieved easily

through consumption of the many C_3 plants, such as squash and beans, that were farmed on the south coast. It may also have its origin in the camelids consumed, who had a more C_3/C_4 signal.

In terms of social differentiation in the Late Intermediate Period population, the homogeneity of the results suggests few differences at first glance. There are no differences between adults and juveniles nor males and females in any of the tissues for which it was possible to test. The range of nitrogen isotope values can be interpreted as varying levels of terrestrial meat consumption (e.g. infrequent, moderate, daily), which might be socially driven. There is also some variation in the carbon isotope value - the most parsimonious explanation being a varying level of maize consumption. There is no correlation between carbon and nitrogen values in the bone data, which suggests that access to meat and maize are not linked. Whether food was used as a tool for maintaining social status or whether it is a reflection of personal preference is difficult to ascertain here.

In terms of economic structures in the Late Intermediate Period the three hair trends suggest that there were different subsistence strategies practised in this period. Firstly, some individuals ate an isotopically constant terrestrial diet. During this period the environmental conditions of the lower valley had improved and food should have been more readily available. Therefore food management may not have been an ongoing concern, although this does not rule out storage of foods. The more terrestrial nature of the nitrogen isotopes mirror patterns observed for the earlier periods in the lower Ica Valley, in that the local population did not routinely consume marine products. The C_4 signal, especially in comparison to earlier periods, suggests these individuals concentrated on maize, or possibly kiwicha, agriculture. Without contextual information for this population from the lower valley the conclusions remain somewhat open.

Secondly, a small number of individuals alternated their use of two types of resources, either between resources typical of the lower valley and marine resources, or the lower valley and higher altitudes. There is good evidence for links with the coast during this period, with the Late Intermediate Period site H-8 in Samaca littered in marine shells. Near the mouth of the Río Ica , two large shell middens attest to the rich fishing industries of the past, one of which has been dated to the Late Intermediate Period by the material culture associated with it (Uhle 1924). It is likely that these individuals were engaged in trading activity between different

resource areas, such as the coast, the valley and the highlands, and the regular shifts attest to the constant yet slow movement through the landscape.

Finally, some Late Intermediate Period individuals relocated between the lower valley and the coast. As already mentioned there is evidence for settlements both in the lower valley and at the coast. It is not unreasonable that individuals moved between the two areas. The coastal fishermen would have needed to access valley areas in order to grow or source cotton for fishing nets (Marcus *et al.* 1999). The movement of goods and people between the coast and lower valley was therefore probably a two way movement. Relocation of individuals could have been for economic reasons but also social ones, such as marriages or for political reasons.

8.6 Further Analyses on the Middle Horizon Data Using Ecological Modelling

The analysis of the Middle Horizon data in Section 8.4 revealed several groupings of individuals in tissues which have different resolutions. These data need further investigation in order to clarify and interpret how these groups relate to each other and the dietary choices that were made in the past.

Several different explanations have been offered for the observed signals in all the tissues and these suggest different dietary strategies were employed by different groups. Ecological studies have used stable isotope studies as a robust measure in investigating dietary niche width, i.e. the variation in the range of foods consumed by different populations. Analysis of the variance of the isotopes over different temporal scales has been put forward as a simple yet theoretically strong technique to do this. Ecological studies show that individual preference will often influence what is eaten rather than the availability and range of foods on offer (Bearhop *et al.* 2004), which has resonance in the human data here. Different dietary strategies are labelled by ecologists as 'specialist', i.e. individuals who consume a very limited niche diet, and 'generalists' of which there are two types - ones who consume a mix of all available resources, and others whom have a wide range of choice but choose to consume only a narrow range of foods (Bearhop *et al.* 2004). The variance of the stable isotopes in these groups will differ according to the range and isotopic types of foods consumed. This type of modelling can be modified for use in archaeological populations, where the identification of specialists and generalists in terms of diet are akin to those of consumers of a constant isotopic diet (whether by choice or narrow availability) and consumers reliant on

isotopically divergent seasonal produce or resources from different ecosystems, which necessitates a switch between the dietary resources. The first group could either be environmental specialists in that they consume a limited range of foods because that is all that is available to them or they could be social specialists choosing to eat certain products despite a wide availability. The second group can be thought of as divergent generalists as no particular isotopic food resource appears to be preferred over any other.

Working with the assumption that different resources are isotopically distinct it is possible to differentiate between specialist and generalist through the variance in the isotopic results from short-term compared to long term tissues. Short-term tissues, such as hair, will give dietary information that will capture the potential variance within the diet for each individual, whereas long-term tissues like bone analysed at inter-individual (i.e. population) level will vary depending on the types of feeders. Clear differences in dietary choice have already been observed in the hair data, with trend 1 showing low variance and trends 2 and 3 higher variance. Following Bearhop *et al.* (2004) variance modelling, trend 1 is a specialist group and trends 2 and 3 are divergent generalists. If the strategies of the groups favour different resources as is possible in a mixed C_3/C_4/marine environment then the bone data should be able to identify the existence of different strategies through the overall variance in the population, as long as all the groups do not favour a mixed isotopic diet. This can be summed up in the following diagram (Figure 8.48).

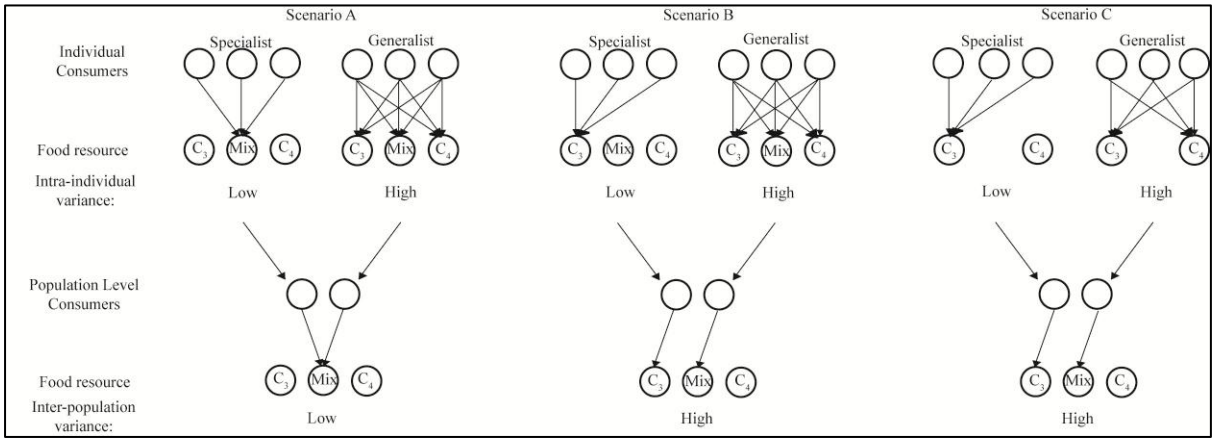

Figure 8.48 Theoretical isotopic variances expected within individual data (top line), i.e. segmented hair data, and within population data (bottom line), i.e. bone data, modelled for different diets consumed.

If this model is applied to the carbon isotope data from the Middle Horizon, then the three terrestrial carbon isotope sources would be C_3, C_4 and an intermediate mixed C_3/C_4 that originated from a single source, e.g. camelids. Marine and freshwater food resources can be ignored as there is little $\delta^{15}N$ evidence for these being consumed. This model is slightly complicated due to the inclusion of the intermediate C_3/C_4 food source, but it would be foolish to ignore this indirect route of a mixed carbon signal as there is evidence for it from the camelid $\delta^{13}C$ values which have values spanning the scale from -12‰ to -19‰. A much simple C_3 versus C_4, specialist versus generalist model would always theoretically show high variance in both the intra-individual and inter-population levels (see Scenario C in Figure 8.48).

With the addition of the intermediate carbon isotope resource any variance seen at the population level is dependent on the carbon isotope source the specialists consume. This general model helps to relate the hair and the bone data and the concepts central to the discussion of social identities related to food choices. One major disadvantage is the inability to distinguish between environmental and social specialist, although the multi-disciplinary nature of archaeology can help resolve this.

The groupings identified in the hair data are not apparent in the bone data, because the variance between these groups is low. However, there is high variance seen between the clusters identified by PCA analysis on the bone data, which suggests there are different dietary groups, which were not identified in the hair data.

Using the whole population bone collagen data, the isotopic range in carbon is wide for Clusters 1 and 3. However, basic statistical descriptives show these to be outliers which skew the data. When the outliers (identified by dashed circles on Figure 8.49) are removed, the data in each cluster become normally distributed and the isotopic variance within Cluster 3 becomes very low (0.3‰ for carbon and 0.4‰ for nitrogen), indicating it is a specialist group. The isotopic variance in Cluster 2 is high (3.0‰ for carbon and 0.4‰ for nitrogen), as none of the data points are deemed outliers. However, using a Kolmogorov-Smirnov Z test, the juvenile group (Cluster 2) were identified as being significantly different from the adults. Thus this group can be considered as generalists, i.e. their dietary niche is wide, although whether they are divergent generalist is unknown due to the lack of hair data. The magnitude of variance for Cluster 1 falls in between the two other clusters for carbon (0.9‰) but is very similar for nitrogen (0.5‰). This cluster contains all of the individuals from the hair trends

data making it impossible to characterise the whole cluster as generalist or specialist based on the variance in the bone data.

Therefore using the two datasets, a range of statistical procedures and the ecological modelling, the population can be divided into four groups (Figure 8.49). Two are clearly specialists of some sort - one consuming mixed C_3/C_4 resources (hair data trend 1; circled in green on the graph) and one consuming C_4 resources (bone data; red triangles). The juvenile group who consumed primarily C_3 resources are generalists and clearly separate from the adults (bone data; red squares). Finally, there is one divergent generalist adult group (hair data trends 2 and 3; circled in blue).

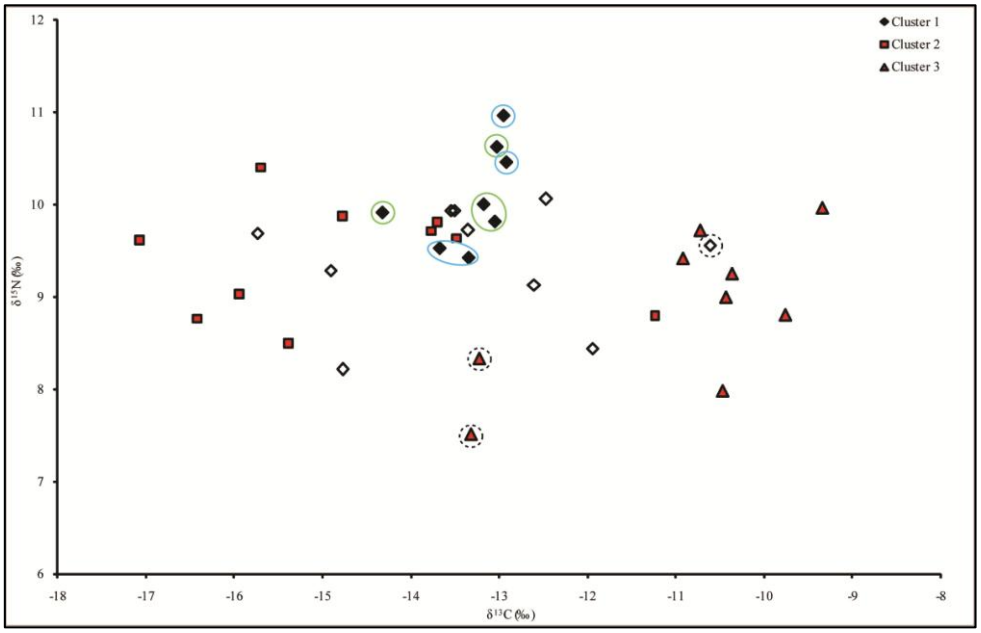

Figure 8.49 Isotopic data for specialist and generalist groups from bone samples. The clusters are those identified through PCA analysis of the bone material and identify two specialist groups - clusters 2 and 3. A further specialist group, identified through the segmental analysis of hair, is circle in green. The generalist group, identified in the hair samples, is circled in blue. Those individuals who have not been assigned 'specialist' or 'generalist' are represented by open symbols or crosses. The individuals deemed as outliers are indicated by the dashed circles.

It is clear then that through bone data alone it is not possible to identify the all the food strategies employed by individuals.

In sum, the following groups have been identified:

- Specialist adults consuming a C_4 based diet
- Specialist adults consuming a mixed C_3/C_4 diet, which includes the two potential migrants (hair trend 1)
- Generalist adults consuming a mixed C_3/C_4 diet (hair trends 2 and 3)
- Juveniles consuming a predominantly C_3 diet.

Specialist Adults Consuming a C_4 Terrestrial Based Diet

This group contains both female and male adults from Middle Horizon Cemetery 755. It is interesting to note how only one cemetery is represented in this group but both sexes are. The high $\delta^{13}C$ values of this group immediately suggest that maize was responsible for this value and indeed this is the interpretation put forward by studies with similar results (Finucane *et al.* 2006; Horn *et al.* 2009; Kellner and Schoeninger 2008; Slovak and Paytan 2011). A plant resource is the most likely dietary input that would have caused these elevated carbon values as the camelid carbon isotopic values are mostly below that of the humans, with a mean of -15.8 ±2.5‰. There are other C_4 plants in the region, many of which could have been consumed (Cadwallader *et al.* 2012), but none has such a compelling social argument as maize. This crop was clearly of great importance to the Wari populations as was noted in Chapter 2. The importance of maize as an elite food, and as the drink *chicha*, has also been documented for the Inca period and it is thought that this stemmed from earlier Middle Horizon traditions (Valdez 2006). Thus this group were likely to be elites. Their specialist diet is socially derived yet there were environmental constraints on the production of maize in the lower Ica Valley at the time (Beresford-Jones *et al.* 2011b). This means that the maize consumed by these individuals would have to have been transported into the basin from elsewhere, making it even more of a high status item due to the cost of transportation. Alternatively if maize was grown in the lower Ica Valley these individuals consumed the vast majority of it.

Specialist Adults Consuming a Mixed C_3/C_4 Diet

These are the individuals characterised by the constant isotope signals in the hair data (trend 1). The reasons for the constancy of the isotope data remain the same as discussed earlier when investigating seasonal trends (Section 8.4.2), that is, that these individuals had unfaltering access to stored foods, ensuring food security; or, there was a constant supply of imported foods; or finally that there was actually an abundance of food resources from which these individuals could easily consume a mixed diet. This last explanation can be dismissed based on the available environmental evidence (Beresford-Jones *et al.* 2011b; Eitel and Mächtle 2009).

The precise dietary sources that are responsible for this mixed C_3/C_4 isotopic signal are unknown. The group may have had year round access to camelids who had been foddered on a mixed diet, which is supported by the camelid isotopic evidence and the $\delta^{15}N$ values of the humans. As the tissues analysed preferentially reflect the protein source of the diet the constant diet suggests a constant supply of a terrestrial protein. A second explanation would be that this group had a constant and equal access to C_3 and C_4 plant foods over the course of the year. Due to the apparent environmental instability during the Middle Horizon storage and careful management of resources would have been necessary. Food storage is a very real possibility in the lower Ica Valley as the naturally dry climate enables dehydration of food for storage. A resident group with a very constant diet suggests that their food management has gone beyond the level of the layman as they are wealthy enough to have a surplus of foods to store for the future, especially as the drought affecting the Middle Horizon would have made accruing a surplus difficult. Likewise, an unfaltering access to meat resources suggests that these individuals were high status or wealthy enough to regularly command such an important and presumably costly resource. These reasons make the specialism of this group both socially and environmentally driven. This may indicate that this is a local elite group, a notion supported by the life history data. This group also contains the two individuals with significant dietary changes over the duration of their lifetime. This could be evidence that elite status could be acquired as the dietary change is not universal and the juvenile group had a range of $\delta^{13}C$ bone values. Or it could be that there was a ritual transformation for elite children as they passed a certain life stage. The small number of individuals that this affects make it difficult to draw any strong conclusions, although it does support the idea of these individuals being elites, as they would have been fewer in number than the non-elite section of the population.

Divergent Generalist Adults Consuming a Mixed C_3/C_4 Diet

This group saw two types of fluctuating dietary trends in the segmented hair data - one regular and the other not. This suggest a reliance on different food types throughout the year and the patterns in which they were consumed suggests two sub-divisions within this group: a) individuals with regular fluctuating diets; and b) individuals with irregularly fluctuating diets. The explanations for these remain the same as when discussed in the seasonal diet section. These groups are interpreted as non-elite as they do not appear to have commanded high status foods, such as maize, on a regular basis and are reliant on seasonal or distant, and therefore potentially difficult to control, resources in order to sustain their diet. They are also potentially people engaged in activities throughout the landscape (e.g. traders).

Juveniles Who Consumed a Predominately C_3 Diet

The separation of the juveniles into a separate group has interesting implications on the social distinctions that existed in the Middle Horizon. The fact that the diet is predominately C_3 suggests that C_4 foods, such as maize, were restricted foods for the majority of this group. The act of eating a socially valued food, such as maize, endows the individual with the symbolic associations of the food (Twiss 2007). Thus the juveniles can be viewed as not having elite status. The tooth-bone data only revealed two individuals with dietary changes over the course of their lifetime, perhaps because only children of elites underwent this transformation but small sample sizes hamper the strength of any conclusions drawn. Thus it is unclear how many children in the Middle Horizon underwent a dietary and probably social transformation between childhood and adulthood.

Andean social rituals involving children were noted by Spanish chroniclers after the conquest of Peru, supporting this idea as children being of a different social class. At the age of 4 or 5 years old, the infants hair was cut for this first time and had an accompanying festival with offerings to a *huaca* (Arriaga 1621). Similar celebrations and rituals were also said to have occurred when the children were aged 8 or 10 years of age and were first given breechclouts (loincloths) to wear (Arriaga 1621). It is reasonable to suggest some age-related rituals took place in the Middle Horizon and that foods were used as a tool for creating and transforming social identities.

Summary

The Middle Horizon populations from the lower Ica Valley have a diverse diet, encompassing both C_3 and C_4 resources of terrestrial origin. It is at odds with the published archaeobotanical data (Beresford-Jones *et al.* 2011b) in some respects as domesticated resources, such as maize, which is absent in the botanical remains, seem likely to have played an important role in the diet. There is also little direct evidence for the consumption of marine foods, which were abundant in the middens.

The identification of the four specialists groups has not been achieved before in any published study but has been done so here thanks to the combination of the multiple tissues giving information at different resolutions and from different life stages. These groupings shall be discussed further in Chapter 9 with respect to the wider archaeological context of the south coast.

8.7 Chapter 8 Summary

The isotopic results from each period have been subjected to an in-depth analysis in this chapter. With greater sample numbers in the Middle Horizon and Late Intermediate Period cemeteries it was possible to make stronger interpretations than in the earlier to time periods.

Briefly, the isotopic dietary evidence for the Early Horizon population is somewhat inconclusive. Hunting of wild animals was practised but beyond this it is difficult to comment on the degree to which reliance on wild or domesticated resources took place. The Early Intermediate Period Late Nasca population used a mixture of both C_3 and C_4 terrestrial resources and were likely to be relying mainly on agriculture, although the use of wild food resources cannot be ruled out. The Middle Horizon data show the most complex picture out of all of the time periods. Through extended analysis, it has been possible to show four different dietary groupings. Food was being used in this period to mark social status and identity. Greater movement through the landscape is also evident during this period and there is evidence for elites on the coast. Finally the Late Intermediate Period Ica-Chincha period saw the greatest reliance of any population on maize. There is some evidence for social status differences although this is debatable. Movement between the coast and the rest of the valley has been identified in the hair results.

Chapter 9 Discussion - Results in the Wider Context

This chapter places the results from each time period discussed in the previous chapter into the wider context of the south coast. The hypotheses proposed for each time period in Chapter 1 are evaluated along with the existing published theories and debates that were detailed in Chapter 2. The last section of this chapter discusses how the results and interpretations of this thesis impact on the discipline of archaeology not just in South America but globally.

9.1 Early Horizon

The hypothesis proposed for the Late Ocucaje period was that agriculture was a significant part of the subsistence regime of the people and they were undergoing a cultural transition at a similar time to an economic one. The isotopic results discussed in Chapter 8 paint a somewhat inconclusive picture of the dietary practices of the people of the lower Ica Valley. People consumed a mixed terrestrial C_3/C_4 diet probably with elements of wild and gathered foods from the coast, *lomas* and riparian floodplains. No social distinctions were being made using food (that can be detected isotopically) and very few comparable studies exist against which to judge these results. Archaeobotanical studies suggest that the consumption of these domesticated crops appears to have increased from the Early Ocucaje phase (c.750 B.C.), where no cultivars are present in the archaeobotanical record, to the Late Ocucaje phase, represented by data from Cemetery 1004, which includes maize, peanuts, squash, manioc and pacay. Yet the extent to which these cultivars were relied upon in the Late Ocucaje is unknown. In comparison to the Late Nasca data from the lower Ica Valley, Late Ocucaje people do not show the isotopic signal of the classic agriculturalists of this area. Rather their diet suggests more C_3 foods, such as beans, squash and huaranga, the latter wild plant resource being proposed as significant in the diets of the population given the archaeobotanical record (Beresford-Jones *et al.* 2011b).

The only previously published isotopic data for the Ocucaje period are from the hair of five mummy bundles from the Paracas peninsula dating to the early part of the Early Horizon (Horn *et al.* 2009). These individuals had much higher $\delta^{15}N$ values (approximately 15‰) and $\delta^{13}C$ values in the region of -16‰ to -15‰. The nitrogen values reflect an aquatic diet. The carbon values suggest a largely marine diet based on the isotopic values of modern marine

fauna (Tieszen and Chapman 1992). The high level of aquatic foods in the diet of these mummies is unsurprising, given their location of burial on the coast. Further inland, demographic data from Palpa do not strongly support the notion that Late Paracas populations from this part of the south coast were agriculturalists. The mortality profiles show an unexpectedly low infant mortality rate (Cagigao 2009). This may be an artefact of the sample size and so it remains unclear whether the true mortality pattern would reflect an agricultural community or not. The stature of the Paracas population from Palpa is considerably shorter than their Nasca and Middle Horizon counterparts, which may indicate overall poor living conditions and an inadequate diet in the Early Horizon. This proposal is supported by the high levels of cribra orbitalia (Cagigao 2009) - a condition often associated with anaemia but probably multi-factorial in origin, with poor standards of health and hygiene contributing to the prevalence of the condition (Walker *et al.* 2009). No incidences of cribra orbitalia were observed in the lower Ica Valley populations, although few crania were present. It was not possible to comment on their stature due to incomplete skeletal samples.

The spread of the Late Ocucaje bone collagen data from the Samaca basin suggests a generalist strategy in terms of ecological modelling (Bearhop *et al.* 2004), i.e. the dietary niche was wide, although the segmented hair data suggest individual preferences for particular food types. It has been argued that wild foods in the past likely played a crucial role in the diet (Beresford-Jones *et al.* 2011b; Cadwallader *et al.* 2012), yet the isotopic data do not suggest that the diet varied seasonally. This latter fact in itself suggests a probable regulation of food supplies, whether through successive harvests of cultivars or storage and provision of foods, supplemented with seasonally available wild foods.

The apparent disparity between the lower Ica Valley dataset and the other available south coast data may be due to bias in the reporting of archaeobotanical data, which is the most abundant line of evidence for diet during this period. The few published works available for the Early Horizon on the south coast talk about the agricultural nature of the society yet they report both wild and domesticated plants and animals in their archaeobotanical and faunal assemblages. Wallace (1962) includes several wild plants, which have been shown to be edible (Cadwallader *et al.* 2012). DeLeonardis (2005: 35) reports "maize, beans and other seeds" but fails to mention if they are wild or domesticated. Lumbreras (1974: 59) mentions a long list of domesticates that were cultivated but only briefly mentions that hunting and gathering were still practised. Silverman's (1996) hypothesis on the lack of importance of marine resources on the south coast is supported by the isotopic evidence presented here.

This is particularly striking in view of the malacological evidence from the lower Ica valley and evidence, albeit small, from Callango and Cerillos further upstream (DeLeonardis 2005; Wallace 1962). An abundance of marine shells has been noted in the Early Ocucaje middens and Late Ocucaje cemetery 1004 (Beresford-Jones *et al.* 2011b). This profusion of remains is misleading in light of the isotopic evidence and the potential bias in preservation and taphomony of these remains, perhaps because of their durable nature, should be considered in the future before they are used to make dietary arguments.

It is perhaps an over emphasis of the presence of domesticates that has occurred in much of the literature for this period (cf Beresford-Jones *et al.* 2011b) and the sites all had a much more mixed economy than is widely believed. Given that people in the Nasca period are considered to have been true agriculturalists (with input from wild resources), there is some evidence here for an economic transition occurring between the Late Ocucaje and Early Nasca, with the increased use of domesticated plants. Moreover worldwide, this transition from subsistence based upon mainly hunting and gathering to mainly agriculture actually falls along a continuous spectrum of subsistence strategies (Smith 2001). What we can see here is the increase of domesticated plants from the Early Ocucaje phase to the Late Ocucaje, but this comes mainly from the anecdotal archaeobotanical evidence rather than the stable isotope data.

A similar increase in the use of domesticated plants is seen on the north coast of Peru at roughly the same time. The expansion and adoption of maize agriculture have been proposed as occurring in the period preceding the start of the Moche state, i.e. during the emergence and establishment of what became one of the largest states on the north coast to have existed in the Pre-Columbian era (Lambert *et al.* 2012). Stable isotope evidence ($\delta^{13}C$) from mineral phase of bone (apatite) and tooth enamel show that in the Guañape (800-400 B.C.) and Salinar (400-1 B.C.) phases a mixed subsistence economy, likely including wild and domesticated plants as well as marine resources, was practised. With the development of the Moche culture and state, focus shifted towards more enriched $\delta^{13}C$ sources, such as maize (Lambert *et al.* 2012). As on the south coast with the transition from Ocucaje to Nasca, the north coast of Peru shows an economical and cultural transition occurring at around the same time. Similarly, evidence for social differentiation defined by diet is lacking in the north coast data. In the Moche example, the economic transition is hypothesised to have established politicised economic relationships because, just as in the lower Ica Valley, maize agriculture depended on irrigation technology (Lambert *et al.* 2012). Unfortunately, the Early Nasca

archaeobotanical evidence from the lower Ica Valley still contains no cultivars, except cotton, although this is thought to be an artefact of sampling (Beresford-Jones *et al.* 2011b). Thus without Early Nasca samples, it is difficult to draw parallels fully here as it is unclear by which Nasca phase intensive maize agriculture was practised.

The data so far seem to suggest the gradual adoption of agriculture downstream, over the long Ocucaje Period in the Ica Valley. The Samaca basin can be viewed as distinct from the rest of the valley upstream in terms of its position in the landscape. The narrowing of the floodplain means less vegetated land is present and thus the available resources are more restricted. Agriculture in this part is more difficult due to the lack of cultivable land. Both factors made it difficult for people to live and develop agriculture there and the cost of adopting agriculture as the main subsistence strategy may not have been worth the pay-off at the beginning of the Ocucaje period. Another factor that led to the isolation of the Samaca basin from the economic changes that affected the middle valley may have been its location near to the coast. Although marine resources do not seem to have played a large role in the diet of the Late Ocucaje population, its position relatively near to the coast meant that it had access to a resource that was practically unavailable to the populations further upstream. In combination these two factors may have created a natural division between those upstream for whom agriculture was an easier and more logical economic step than those downstream who had a naturally wider dietary niche. If wild foods were abundant and highly-ranked, either nutritionally or perceptually, then farming would not necessarily have provided more food or a more reliable source of food for a reduced labour cost (Barker 2006: 272; Barlow 2002). It has been argued that the habitat of the lower Ica Valley was still densely forested well into the Early Intermediate Period (Beresford-Jones *et al.* 2009) and as such would have been fecund with wild foods providing little impetus to start farming purely for economic reasons. A similar hypothesis has been proposed for the Zaña and Nanchoc valleys on the north coast of Peru (Dillehay *et al.* 2011) and in the American southwest for the Fremont culture (Barlow 2002). Thus the drive which made the people of Samaca and Ullujaya adopt a largely agricultural base may have been a social one, with the emergence of Nasca.

One of the aims of this research was to investigate whether the inhabitants of the lower Ica Valley were part of a centralised system in the Late Ocucaje phase. Although increasing social complexity is seen at sites upstream in Callango (Massey 1991), there are no clear social distinctions expressed through the diet that can be seen in the isotopic data. It is possible that this is a reflection on the limitations of the isotopic technique, although dietary

divisions were not evident in the comparable pre-Moche populations either (Lambert *et al.* 2012). Consumption of a common resource in different quantities may have provided the distinction, or the way in which the food was prepared, or who did the preparation (Turkon 2007), which would not necessarily show in the isotopic values. In neither the lower Ica Valley or Moche case is there any isotopic evidence for social divisions. These two examples are positioned differently relative to the main centre of socio-political (i.e. the Moche example is close to the centre whereas the, lower Ica Valley is removed from the centre) and thus diet may not be a good indicator of social complexity in these transitional examples.

There is thought to have been some level of influence of the Topará tradition, from the Pisco and Chincha valleys, over the Ocucaje (Paracas) tradition in socio-political and religious matters, and that this interaction led to the development of the Nasca tradition (Peters 2000). All of the socio-political changes that occurred in the later part of the Early Horizon leading up to the Nasca transition seemed to have taken place in the middle Ica valley, or the very edge of the lower valley. The centre of power in the later phases of the Ocucaje period shifted from the Callango basin upstream to the Ocucaje basin. Because of the geography of the Ica river, the middle part of the valley is quite close to the Pisco Valley (c. 80km in a straight line) and thus the closeness of the two areas, which both had independent resources, meant that the economic and social interactions and developments could occur in both places with a high level of contact maintained. The lower Ica Valley was far enough removed from these areas and with limited agricultural potential so that there was no or little political or social involvement of the people of the Samaca and Ullujaya basins. A common iconography and style were shared but it was not until the Late Ocucaje period that the people of the lower valley became incorporated into the economic system, adopting agriculture.

9.2 Late Nasca

My hypothesis for this period, given in Chapter 1, was that agriculture was the mainstay of the diet for this population. A high level of social differentiation was expected in the diet, in part due to the changing socio-political dynamics of the Late Nasca but also in part driven by the declining environmental conditions. The data presented in Chapter 8 do not fully support this hypothesis. Whilst the dietary base is arguably agricultural, no social differences in diet are visible. Also the dietary breadth is quite narrow suggesting a fairly homogenous diet

within the population, although the segmented hair samples show little variation indicating individual food preferences.

Only three other studies have published carbon and nitrogen results from south coast Early Intermediate Period sites, all showing a mixed C_3/C_4 terrestrial diet (Figure 9.1) (Horn *et al.* 2009; Kellner and Schoeninger 2008; Webb *et al.* 2013). Likewise a broad, mixed carbon isotope diet has been seen in studies using carbonate analysis of the mineral phase of bone and teeth (Buzon *et al.* 2012; Knudson *et al.* 2009). Unfortunately, not all of these populations have been assigned specific Nasca phases, with only the Kellner and Schoeninger (2008) and the Buzon *et al.* (2012) individuals dated to the Late Nasca period.

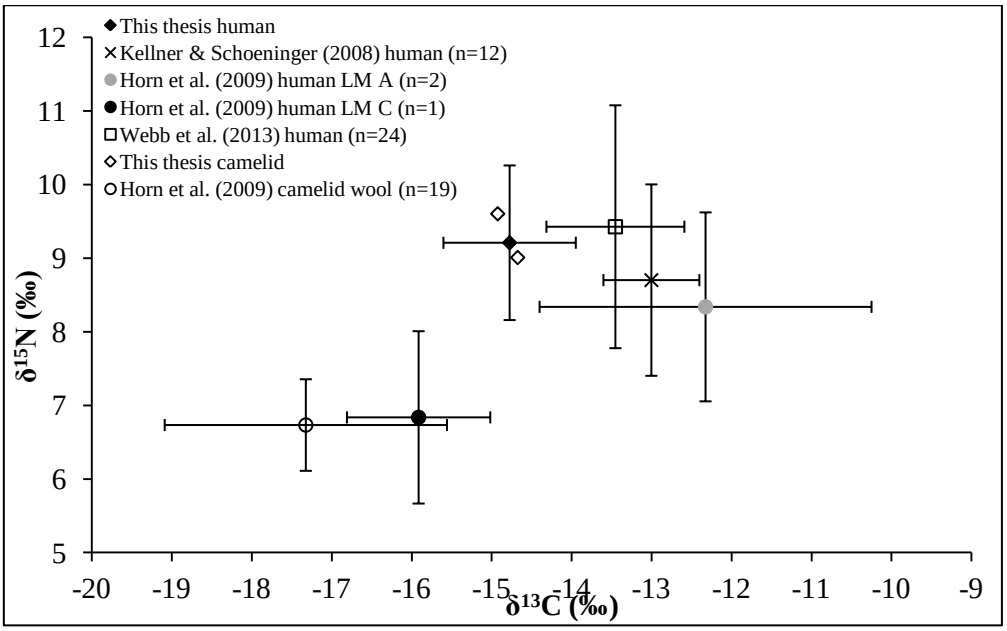

Figure 9.1 Mean Nasca isotopic data from the lower Ica Valley and comparable cemeteries. Error bars represent one standard deviation. The data from this thesis, Kellner & Schoeninger (2008) and Webb et al. *(2013) come from bone collagen. The data from Horn* et al. *(2009) are taken from segmentally analysed hair, and as such the mean and error bars represent the mean and spread along the hair. The values used have been corrected to remove the collagen-keratin offset, using the data from Crowley* et al. *(2010). The camelid wool data have not been corrected.*

None of these studies detected dietary differences within the population (e.g. male versus female, burial type etc) as with the data from the lower Ica Valley. There is evidence for dietary diversity between populations, especially between the populations from the sites Los

Molinos A (LM A) and Los Molinos C (LM C), which have starkly different carbon values. This has been interpreted as a difference in social class between the sites (Horn *et al.* 2009). Statistical differences in carbon (ANOVA, $F(2)= 21.0$, $p<.001$, with post-hoc Bonferroni tests) are also present between the lower Ica Valley data and the data from both Kellner and Schoeninger (2008) and Webb *et al.* (2013). These latter two studies are not statistically different.

The nitrogen values of the humans vary between approximately 5‰ and 10‰ from all four sites. There is no statistical difference in nitrogen (ANOVA $F(2)= 1.1$, $p>.1$) among the data presented here and those of Kellner and Schoeninger (2008), or Webb *et al.* (2013). The data from Horn *et al.* (2009) are also very similar in terms of nitrogen (when the collagen-keratin offset is applied), although the data are from only one or two individuals. Interestingly the camelid wool sample from Los Molinos is similar in terms of nitrogen isotope value to the humans from Los Molinos C. The authors (Horn *et al.* 2009) attribute this to the humans consuming a vegan diet. In my opinion there could be several alternative and more parsimonious explanations, such as the animals having been foddered on different, high $\delta^{15}N$ plants which the people did not consume. Or just like the lower Ica Valley, these camelids may have been suckling juveniles in an environment with an overall lower $\delta^{15}N$ baseline. Finally, the people at Los Molinos C may have consumed a large proportion of legumes which lowered their $\delta^{15}N$ values, as has also been suggested for some individuals analysed in the course of this research. Thus the faunal data should not necessarily be taken at face value against the human data, especially with such a small faunal sample size.

The samples from the Webb *et al.* (2013) and Kellner and Schoeninger (2008) come from sites located relatively closely together - Cahuachi and cemeteries in the vicinity of Huaca del Loro respectively. The Los Molinos sites (Horn *et al.* 2009), meanwhile, are further away near the confluence of the Río Grande and Río Palpa and nearer the foothills of the Andes (see Figure 2.4). The slight variations in the environment of these sites could be a factor in explaining their apparent dietary differences. There may have also been differences in land quality or water availability that meant different crops were easier to grow at different sites. For example, beans, squashes and maize all have approximately the same length of growing period, yet beans need around half the water that maize requires, while squashes need even less (Food and Agriculture Organization of the United Nations 1991). This would suggest that the populations of the lower Ica Valley ate foods grown in drier conditions than the populations at Cahuachi and Huaca del Loro. This could of course also mean that the latter

populations had food moved into these sites from other locations, following the model of using Andean ecological complementarity to exploit better watered areas.

Returning to the social models put forward by other researchers discussed in Chapter 2, my data support some more than others. Both increased and decreased centralisation have been proposed for the Late Nasca period, as well as increasing social complexity (Cook and Parrish 2005; Isla and Reindel 2006; Schreiber 1999; Silverman 2002; Silverman and Proulx 2002). Yet in my dataset I see little evidence to support any notion of greater centralisation proposed by Cook and Parrish (2005). With greater centralisation, one would most likely expect economic integration and social differentiation. Whilst this has been seen in other archaeological investigations (Isla and Reindel 2006), the evidence for it here is limited. The isotopic results shown above do not give a uniform dietary signal across the south coast but instead show a wide spread of data, suggesting local diversity. There is also no evidence for social differences within the populations, which undermines the hypothesis of increased social complexity in the period reflected in its increasingly complex iconography (Silverman and Proulx 2002). The differences among the sites, in my opinion, fit better with the idea of a *decline* in centralisation. The separation of populations *spatially* in order to exploit different resources and ecotones is shown in the isotopic differences among groups. Each population is fairly homogenous, indicating a common dietary source within the group. Thus the data agree far better with the proposal that groups were organised into a series of small units who operated within their local areas for economic means (Schreiber 1999; Silverman 2002). Interestingly there is a considerable difference in both carbon isotope values and architectural styles between the two Los Molinos populations, with the better housed Los Molinos A population having higher $\delta^{13}C$ values. (Horn *et al.* 2009). Although the sample sizes from these two sites are very small, the contrast hints at a form of social complexity at the macro scale, i.e. between sites, rather than at the micro scale, i.e. within sites. It could be that some sites, or rather the people at those sites, commanded better land and so could grow more highly valued but nutrient and water hungry crops such as maize. This reinforces the idea of separate political units in the Late Nasca period who are in competition with each other but share a common identity (Schreiber 1999; Silverman 2002). This also works well with the fact that Nasca trophy heads were from within the Nasca sphere, included all members of society and thus were taken during political conflicts (Conlee *et al.* 2009; Knudson *et al.* 2009; Webb *et al.* 2011a). The model that Isla and Reindel (2006) propose of these smaller units forming a state cannot be supported by the isotopic evidence at this current time.

The diversity in the human isotope data suggests local adaption of subsistence regimes to suit particular local conditions, which suggests also that deterioration in environmental conditions had a profound effect on these populations. Sadly, there is a lack of Early Nasca isotopic evidence which might provide a Nasca 'baseline' for a subsistence pattern during environmental stability against which this evidence could be judged. Maize is certainly not a staple during the Late Nasca based on the isotopic evidence, and it is known to have high water requirements (Food and Agriculture Organization of the United Nations 1991), yet it is reported in archaeobotanical assemblages from this period (Beresford-Jones *et al.* 2011b; Horn *et al.* 2009). Beresford-Jones *et al.* (2011b) propose based on archaeobotanical evidence that there is increased agriculture during this period, culminating eventually in deforestation and salinisation of the land. The evidence as a whole suggests that the changing environment was eliciting responses from the populations who had not completely altered their subsistence strategies in the Late Nasca period. The idea of no major upheavals in the Late Nasca is also supported by the presence of populations in the lower reaches of the valleys (Beresford-Jones *et al.* 2011b; Reindel 2009). The declining environmental conditions are thought to have been responsible for major resettlement to the middle and upper valleys (Schreiber 1999; Silverman 2002), but the continued presence of people in the lower valley suggests that the environmental decline there was not as severe as postulated. This could be partly due to the unrefined dating of the sites using a ceramic sequence for which there are relatively few radiocarbon dates and as such there could be temporal discrepancies of a hundred years or so between the populations studied in the different valleys.

Only with more samples, and better contexts for the samples will it be possible to comment more on social differentiation beyond sex differences.

9.3 Wari Middle Horizon

In Chapter 1 I hypothesised that the isotopic results of the population from the lower Ica Valley during the Middle Horizon would reflect what has been observed in the rather scanty archaeobotanical record, i.e. that the people returned to relying on wild foods and so would have been isotopically similar to the Late Ocucaje population. I also hypothesised that diversity would be present in the diets due to the fragility of the environment putting stress on the population's ability to supply themselves with food. The first part of this hypothesis is not supported at all by my data, whereas there is strong evidence for social distinctions using

food. The Middle Horizon populations in general have more enriched $\delta^{13}C$ values compared to the Late Ocucaje and the Late Nasca. However, the spread of the data for the Middle Horizon is much wider than the preceding periods (see Chapter 6 for details).

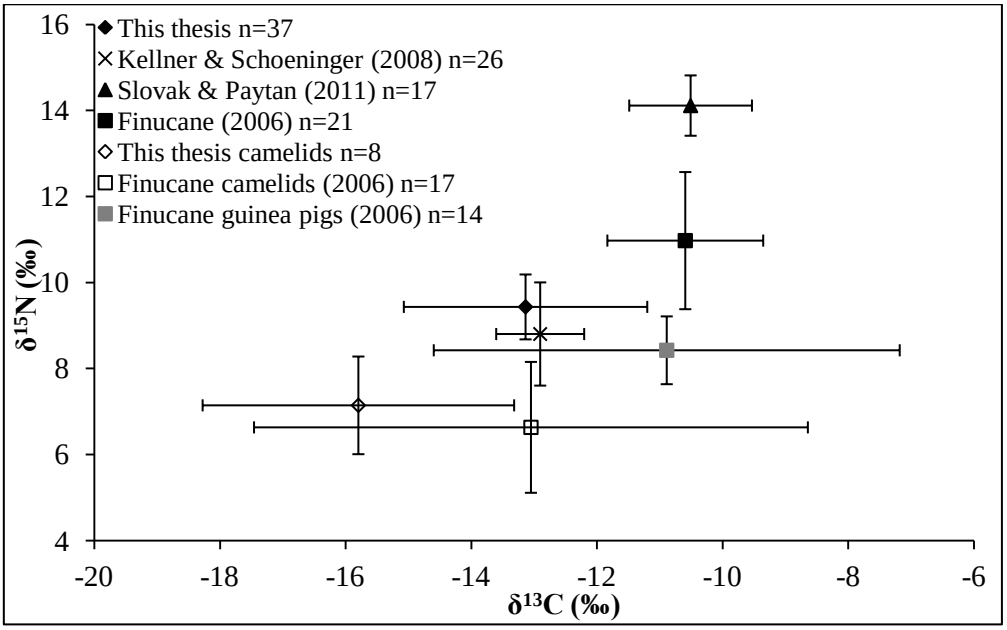

Figure 9.2 Carbon and nitrogen isotopic data from both human and faunal bone collagen from comparable Middle Horizon populations.

Only carbon and nitrogen isotopic studies using adults have been published for other south coast Middle Horizon populations. In comparison to these, the lower Ica Valley adult data are similar to those from the Las Trancas valley to the south (Figures 9.2 and 9.3). Yet there are clear differences between the carbon and nitrogen isotope values of Middle Horizon populations at the highland site of Conchopata (which also analysed only adults) (Finucane *et al.* 2006), the coastal site of Ancón (Slovak and Paytan 2011), and Las Trancas (Kellner and Schoeninger 2008) and the lower Ica Valley data. The Las Trancas and lower Ica Valley data are most similar and show no statistical difference in either isotope (carbon Kruskal-Wallis $H(3)= 40.3$, $p<.001$ with post-hoc Mann-Whitney tests; nitrogen Welch's ANOVA $F(3)= 45.4$, $p<.0001$ with post-hoc Games-Howells tests). The sites of Conchopata and Ancón are both significantly different in both isotopes from Las Trancas and the lower Ica Valley populations. Conchopata and Ancón are not statistically different from each other in carbon isotope value but are so in nitrogen isotope value. The difference in the nitrogen isotope

between these two sites is a function of the marine based diet of Ancón compared to the C_4 terrestrial diet of Conchopata, which is not surprising given their respective locations (see Figure 2.3).

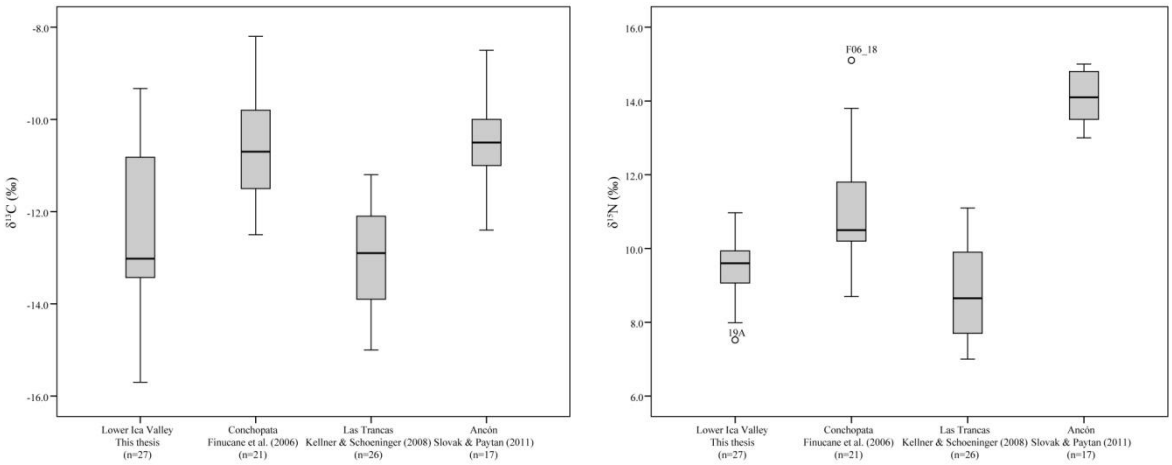

Figure 9.3 Carbon (left) and nitrogen (right) isotopic values for various studies of Wari Middle Horizon populations. All data are from bone collagen.

None of these studies found any evidence for social differentiation in diet in the adult population, probably because they only analysed bone collagen. The lower Ica Valley data have a much wider carbon isotopic range (6.4‰) than the other sites (Conchopata 4.3‰; Las Trancas 3.8‰; Ancón 3.9‰). This dietary breadth is explicable through the identification of the three discrete adult dietary groups discussed in Chapter 8. Perhaps the narrowness of the other three sites is an indication that such groups did not exist in these sites yet Las Trancas and Ancón are hinterland sites like the lower Ica Valley.

Wari cultural influence appeared to have an effect on diet at Ancón but not in Las Trancas (Kellner and Schoeninger 2008; Slovak and Paytan 2011). In Ancón, a dietary shift has been recorded from the early to the late Middle Horizon with a decrease in marine foods and an increase of a C_4 terrestrial protein resource, concluded by Slovak and Paytan (2011), to be maize. However, their lack of faunal analyses means that it is unclear if the C_4 terrestrial signal is due to direct or indirect consumption of C_4 resources. At Las Trancas on the other hand there was no change in isotopic values between the Middle Horizon and the period immediately prior to it (Kellner and Schoeninger 2008). However, both authors have

proposed that local population were engaged in trade or exchange relationships with the highland Wari empire. It has been proposed that maize, a much needed supplement due to the uncertainties caused by El Niño phenomena, was exchanged on the coast for local resources (Slovak and Paytan 2011), whilst at Las Trancas cotton was grown and exchanged with the highland Wari (for unknown goods) (Kellner and Schoeninger 2008).

The interest of the Wari empire in the peripheral lands was likely due to the range of different resources available there. The abundance of marine resources and cotton in Middle Horizon midden and mortuary contexts in the lower Ica Valley (Beresford-Jones 2011) may be a reflection of the empire's economic interest in the area, similar to the reasons put forward for their presence in Ancón and Las Trancas (Kellner and Schoeninger 2008; Slovak and Paytan 2011). An abundance of cotton remains has also been found in the Callango basin dating to the Middle Horizon (Roque *et al.* 2003). This fits with notions of long distance trade moving between the lower Ica Valley and higher altitudes, transporting cotton which cannot be grown in the highlands of the Wari heartland and yet was a key element of their textile manufacture. In return the Wari may have brought back maize to feed the elite group. However, the exploitation of crops by the Wari in this area remains rather at odds with notions of a dramatic worsening of the environmental conditions at the time.

The cotton recovered in the lower Ica Valley middens has been identified as *Gossypium barbadense* (Palmer *et al.* 2012). This species is tolerant of saline conditions (Ashour and Abd-El'Hamid 1970) and has a moderately low sensitivity to drought (Food and Agriculture Organization of the United Nations 1991). Maize conversely requires soils with high nutrient availability and its greatest limiting factor in terms of yields is moisture availability (Wilsie 1962: 382). Although it is a C_4 plant and therefore theoretically drought adapted, it nonetheless requires large quantities of water to produce high yields (Wilsie 1962: 382). As well as being highly sensitive to drought conditions, it is also moderately sensitive in its salt tolerance (Food and Agriculture Organization of the United Nations 1991, 2002). Of course, there are many varieties of maize, some being more drought tolerant than others, but in general it is not well suited to very dry conditions. These characteristics of the two crops might naturally elicit a switch from maize to cotton as the main crop of choice when the environment started to decline. The ability to produce cotton suggests that perhaps other halophytic plants or at least those that had some tolerance of saline conditions, for example *Phaseolus vulgaris* and some varieties of *Cucurbita pepo* (Food and Agriculture Organization

of the United Nations 2002), were also possible to cultivate, and thus the lower Ica Valley could have supported a small resident population.

The data that I have gathered and interpreted for the lower Ica Valley have powerful implications for our understanding of the Wari in the coastal peripheries of their empire. In Chapter 2 current theories concerned with the mechanisms of imperial control on the coast were given, which I shall revisit here using the lower Ica Valley data. Conlee (2010) proposed that the coastal hinterlands shared a new religion and culture with the highlands but that there was no complete replacement of prior regional practices. The lower Ica Valley data show some supporting evidence. Firstly, the tomb architecture and artefacts, especially the abundance of raw cotton, in the looted cemeteries are typical of Wari Middle Horizon burial practices (Isla 2009; Valdez *et al.* 2006). I have identified several adult groups with very distinct dietary strategies, which I interpret as locals and highland elites. The presence of the two local groups with different dietary strategies suggests that a local political hierarchy that existed prior to the Wari influence was maintained, although no social differences were identified isotopically in the Late Nasca samples used in this research. It is possible that these two populations from the lower Ica Valley were not fully contiguous as there is some uncertainty in the precise dating of the cemeteries. Alternatively the ways in which social differences were expressed could have changed, with food being used in the Middle Horizon unlike the prior period. The separate juvenile group who were likely to be locals also hints at a possible local custom of restricting children's food resources, although no other isotopic studies of juveniles has taken place from Wari sites. The oscillating dietary regimes that suggest use of multiple production zones could indicate the operation of *ayllu* structures by local populations. This would suggest a continuation of local practices and maintenance of kinship ties despite the presence of an overarching authority.

With more contextual information for the lower Ica Valley it may be possible to elucidate more fully the extent of social impacts that Wari influence entailed on the coast.

Conversely it has been proposed that Wari was a military expansion empire that took trophy heads in violent circumstances so as to maintain control over the populations in the hinterlands (Conlee *et al.* 2009; Tung and Knudson 2011). There is no direct evidence for trophy head taking from the lower Ica Valley, or inter-personal violence, although as noted in Chapter 6 the sample cannot be taken as truly representative. In my opinion the dietary diversity and social grouping seen in the lower Ica Valley data suggest that there were

obvious social or ethnic differences maintained between highlanders and those local to the hinterland areas. Whilst there is no evidence of military control in the lower Ica Valley, such evidence is notoriously difficult to see in the archaeological record and there certainly is evidence for active and direct control of the south coast. This suggests, as does militaristic intervention, that the relationship between the periphery and the highland core was not necessarily a congenial one.

The presence of highland elites on the coast has been a contentious issue in recent studies (Buzon *et al.* 2012; Conlee *et al.* 2009; Knudson and Tung 2011; Slovak and Paytan 2011), especially those using isotopic data as evidence. At the site of Ancón, approximately 40km north of Lima, strontium isotope analysis identified one non-'local' individual, in the geological sense (Slovak and Paytan 2011). This teenage female had $^{87}Sr/^{86}Sr$ values similar to those from Ayacucho so that she might represent the movement of elites from the heartland to the coast, so as to control the movement of marine resources up to the highlands (Slovak and Paytan 2011). On the south coast a mainly 'local' burial population with the presence of two non-'local' individuals potentially from the Wari heartland has been proposed for the sites of La Tiza and Pajonal Alto also using strontium isotopes (Buzon *et al.* 2012; Conlee *et al.* 2009). It has been speculated that these highland individuals came down and settled in the hinterlands by making agreements with the local elites (Buzon *et al.* 2012). From the site of Beringa, midway between Wari and the outpost of Cerro Baúl in the Moquega valley, two individuals were identified as non-'local' using strontium analysis of multiple tissues from each individual (Knudson and Tung 2011), although these individuals do not appear to have any isotopic connections with the Wari heartland.

The Knudson and Tung data (2011) seem to support an absence of elites from the highlands controlling local affairs, whereas the Slovak and Paytan (2011), Buzon *et al.* (2012) and Conlee *et al.* (2009) data hint at the contrary. However, these datasets are based on small numbers of individuals and it remains uncertain where the non-'local' individuals were from. The relocation of these few individuals could be explained instead by the movement of goods and mechanisms of trade and exchange which expanded in Middle Horizon.

Using a different isotopic approach, the lower Ica Valley data support the presence of highland elites on the coast in conjunction with local elites. The highland elites show no dietary change between infancy and adulthood. These individuals therefore always had elevated status. Two interpretations follow. Either, they were second generation elites, born,

raised and buried in the lower Ica Valley. Or, they were first generation elites, born in the highlands who at some point moved to the lower Ica Valley but not making substantial changes to their diet. The previously published isotopic studies claim to have identified first generation highland migrants (elites?) (Buzon *et al.* 2012; Conlee *et al.* 2009; Knudson and Tung 2011; Slovak and Paytan 2011) but because of the nature of the technique used (comparing strontium isotopes signals from childhood to adulthood) second generation elites would not be seen in these studies, as they would not have moved from one area to another. The future application of strontium isotope analysis on the lower Ica Valley material would enable further exploration of the possible migration of these individuals (see Section 10.3). Taking these lines of evidence together, there is now evidence for prolonged presence of Wari elites in coastal hinterland sites.

In sum, I have been able to identify the presence of elite Wari individuals in lower Ica Valley through a different technique to those used in existing studies and furthermore that they used diet to distinguish their social status from the local population. My research suggests that the Wari were clearly adopting their strategy to fit local conditions (both social and environmental), which in the case of the lower Ica Valley, saw both highland and local elites living alongside one another.

9.4 Ica-Chincha Late Intermediate Period

The hypothesis given for the Late Intermediate Period in Chapter 1 proposed that improving environmental conditions would have allowed a return to agriculture for the inhabitants of the lower Ica Valley. Social stratification in the society would not have been caused by environmental pressures but rather an economy based on trade from the coast to other areas for which there is isotopic evidence. The isotopic results clearly suggest a terrestrial, maize based diet. There is some evidence for social stratification through differential access to meat or maize resources. The isotopic homogeneity of the population is striking compared to the Middle Horizon. This suggests that the environment improved significantly to enable a larger population to rely on an isotopically narrower resource base.

At Cerro Azul in the Cañete valley, zooarchaeological data have been used to suggest that there was dietary differentiation between elites and commoners in terms of amount of camelid meat and type of fish consumed (Marcus *et al.* 1999). A distinction such as the one seen at Cerro Azul would not necessarily be seen isotopically, as the marine foods consumed

by all would have masked the critical difference in the amount of camelid meat consumed. In the Ica valley, the data show a differences based on differential consumption of terrestrial resources, although there may have been a small marine component for some individuals. At Cerro Azul camelids could not have been easily herded and thus their meat was a rare and valued commodity (Marcus *et al.* 1999). The lower Ica Valley on the other hand has been proposed as a suitable location for camelid herding (Cadwallader *et al.* 2012), whilst marine resources would have had to have been transported to the Samaca and Ullujaya basins and therefore would have been more 'costly'. Therefore the relative value of camelid meat and fish would have been the opposite in the lower Ica Valley compared to at Cerro Azul. It has been noted that, whilst the burial customs for elites and commoners differed substantially in Ica Vieja, in other aspects of material culture there was little difference between the two classes (Conlee *et al.* 2004). This would suggest that the observed isotopic differences could just be individual preferences and that food would not have been used to maintain social differences.

The lower Ica Valley data suggest an economic and social structure similar to that of the Chincha valley, although at a smaller scale, with social distinction and economic activities that united the coast and highlands through trade. The traders, identified by the trends in the segmented hair, suggest that two different routes were used - one that incorporated the coast and lower (and middle?) valley and the other which did not incorporate the coast but went onto higher altitude areas (lower, middle and upper? valley). There is an abundance of marine shells in the Late Intermediate Period site H-8 in the Samaca basin (Beresford-Jones 2011), supporting the idea of the movement of goods from the coast inland. The Late Intermediate Period site of Huayurí in Palpa has been interpreted as on the route of a llama caravan route moving resources from the coast to the highlands (V. Severoni *pers. comm.*), lending further argument to the presence of trade caravans moving resources through the lower Ica Valley. It has been suggested that there was little elite control over the upper valley parts by the centralised lower valleys (Covey 2008), supporting the interpretation based on the isotopic data that the lower valley populations did not traverse a large vertical stretch of the Andes but instead moved between the lower and middle (and possibly upper) valley. An obvious stop on a trade route up the Ica valley would have been the site of Ica Vieja in the middle valley. As discussed in Chapter 2 this was a large site with indication of social distinctions. Thus transportation of coastal goods likely took part in stages, with exotic goods, such as coca, being brought down from the highlands in return. This proposed infrastructure is rather

different from the wide-scale Chincha model proposed by Rostworowski (1977) because it is at much smaller scale, with economic organisation occurring at the intra-valley level (e.g. lower valley versus middle versus upper) as opposed to the valley-wide level. The idea of economic specialisation, with groups of farmers, traders and presumably fishermen at the coast, does fit well with Rostworowski's (1977) model at this time and has also been observed isotopically further to the south in the Osmore Valley (Tomczak 2003).

An alternative model would suggest that all these movements, and especially those of the relocated individuals, were connected with ideas of *ayllu* reciprocity. For the case of those moving between the lower Ica Valley and the coast, this works well with ideas of horizontal complementarity, which saw the coast and the lower valley agricultural areas linked economically. The other individuals who are moving between the lower Ica Valley and higher areas, conversely, fit better with the idea of vertical exploitation of production zones. As discussed in Chapter 2 the vertical model is often highland-centric and thus its operation alongside a horizontal model does not seem a parsimonious explanation, especially given the evidence for trading operating from the south coast to the highlands in this period (Rostworowski 2004).

Thus I suggest that society during the Late Intermediate Period had a basin-level economic organisation rather than the larger scale trading model suggested by Rostworowski (1977). The entire Ica valley cannot be considered as centralised based on the ideas derived from the lower Ica Valley data, as this implies that administrative powers would have been concentrated in a single centre (based on the Oxford English Dictionary (2012) definition of 'centralised'). The Cañete Valley further to the north was divided into upper and lower valley independent political units in the Late Intermediate Period, providing an example of an alternative model (Conlee *et al.* 2004). Given the mode of the economy, i.e. heavy use of camelid caravans to trade or exchange goods exploited in each zone, the different groups must have co-operated as the economic strategies employed seemed to be mutually beneficial and co-operation made best economic sense. To understand the Late Intermediate Period fully in the Ica Valley substantially more archaeological work needs to be undertaken throughout the length of the valley.

9.5 Implications for the Rest of South America and Beyond

Beyond the south coast of Peru, these data have resonance for several issues common to Andean archaeology and the Americas in general.

Viewed over a broad time scale and the changes of the cultures relative to one another, the isotopic pattern seen in the lower Ica Valley is very similar to patterns seen elsewhere, in the few places where long-term isotopic studies have been conducted. A gradual increase of C_4 resources, i.e. maize, in the diet is observed in both southern and northern Peru (Buzon *et al.* 2012; Ericson *et al.* 1989), and to some extent in central Argentina (Gil *et al.* 2011; Gil *et al.* 2009). Evidence to the contrary has been given for the central highlands around Ayacucho (Finucane 2009), although in my opinion other interpretations may also be advanced in this case. In North America, this pattern has also been observed in numerous locations including the upper New York state (Vogel and van der Merwe 1977), eastern United States (van der Merwe and Vogel 1978) and the upper Mississippi valley (Bender *et al.* 1981). It has been noted that the North American pattern varies temporally and has much to do with not only local environments but also social influences on the diet, and the adoption of maize as the main dietary staple cannot be considered as one event (Schoeninger 2009). That view seems to be supported here, with the coastal Peruvian data differing from the highlands. It seems that maize, the most likely cause of the shift to more positive $\delta^{13}C$ values, had a far reaching economic impact. This transition to reliance on maize agriculture in the Americas was *gradual*, a point often ignored or oversimplified. With domestication maize did not instantly come to dominate the economic regimes of the Americas, but rather it took time, because the process of domestication and adoption is long and slow as some crops were selected preferentially over others (Hastorf 1999; Smith 2001). Whilst the continued use of maize is not under question in this thesis, the observed dietary patterns remind us that we cannot think of the adoption of and reliance on agriculture as a simple and uni-linear process.

This is illustrated by the evidence for wild plant use put forward by others (Beresford-Jones *et al.* 2011b; Cadwallader *et al.* 2012) and supported by this thesis. In this research I have shown that evidence for diets through indirect means such as archaeobotany, iconography or through 'top-down' social theories of economic organisation, are *not* necessarily representative of what people consumed. Just because people could grow certain crops doesn't mean they did, or that it was their main source of food. This was especially important in the earlier periods of the lower Ica Valley and the Andean region, although it also rings true for the Middle Horizon in the lower Ica Valley. The use of wild plant foods, shown to be

an important factor in the lower Ica Valley, needs to be acknowledged more in dietary and economic studies than it has previously especially in the periods preceding the dominance of maize agriculture (see Cadwallader *et al.* 2012 for discussion pertaining to this issue on the south coast).

This research has also shown that the ideas of horizontal and vertical complementarity only seem to work in the later periods for the lower Ica Valley populations. In the case of the Middle Horizon it appears to have operated in some form at the state level but was driven by both social and economic factors. In earlier periods the focus of economic activities appears to be on local resources in the lower Ica Valley. Yet the dataset here is small and some evidence for early use of complementary zones has been shown elsewhere (Webb *et al.* 2013). As with many of the studies of ecological complementarity discussed in Chapter 2, the data here suggest that the system has no great antiquity. Indeed, the strongest evidence comes from the Late Intermediate Period, where a different economic organisation, using both horizontal and vertical movements, is seen not only in the Ica Valley data, but also elsewhere on the south coast (Rostworowski 1977; Tomczak 2003; V. Severoni *pers. comm.*). The evidence for movement about the landscape is much greater in the later periods, which is interesting in the light of linguistic models that propose the expansion of the Quechua language family to the Middle Horizon (Beresford-Jones and Heggarty 2012). This model links the rise and reliance in maize agriculture and language spread, which the lower Ica Valley model derived offers support.

The lower Ica Valley data also suggest that a diverse set of responses - both economic and social - arose due to the decline in environmental conditions, which can be most clearly seen in the Middle Horizon populations. Yet this has only been visible thanks to the isotopic analysis of a *combination* of tissues and thus this research may serve as a model for other similar environments. The remarkable preservation conditions seen in the lower Ica Valley are not universal and as such not all researchers have this advantage. Interpretations based on isotopic data from only one or two tissue types should therefore be made with some caution as for a nuanced dietary reconstruction multiple tissues with different resolutions are needed.

This research also has importance in South America and beyond as it demonstrates that looted human remains can provide a valuable research data, despite the loss of context. Looting is a widespread problem in Peru and in many other areas of the world. The analytical success rate was over 90% for the collagen samples analysed and over 80% for the keratin

samples, showing that with careful selection and sampling of the most appropriate part (e.g. un-sun bleached bone), the application of isotopic analysis is valid and valuable. Because human remains can be aged and sexed, some contextual information can be salvaged, which is enough to perform statistical analyses to explore the data to the same level often applied in studies with good contextual information. It is only the uncertainty in dating disturbed mortuary contexts to specific phases or cultural affiliation which presents a particular problem and this can be overcome through careful choices of cemeteries to sample, and radiocarbon dating[1]. Thus while this approach has proved useful here and is likely to elsewhere, still must be applied with some caution.

The wider aim of this thesis was to look more broadly at the way changes in economic activity and social organisation are visible at the micro and macro levels in the arid environments of the lower Ica Valley and specifically to ask whether these responses are significantly affected by the limitations of the environment. Human existence in deserts and responses to changes in arid environments globally has been often viewed from the position of archaeological sciences, investigating settlement history, land management and changing resource abundance (for example see volumes by Barker *et al.* 2007; Dalfes *et al.* 1997; Hassan 2002). Yet using data obtained directly from the people *themselves* I have placed this research into more of a social setting; for instance, by examining the evidence for social identities created and maintained through the use of food in arid environments. I have shown clearly that in times of food abundance and environmental stability, the use of food as a marker of social differentiation is lower than at time of instability, even when there is a large scale state (e.g. the Wari empire) which could have, and arguably did, provide social solutions (for certain individuals at least) to food insecurity. Thus, it is the scarcity which drives competition and prestige connected to food in this environment.

Social systems using differentiation have also been shown to operate in other arid areas where water variability may have caused food insecurity. For example, in Africa communities on the Senegal River operate within a social hierarchy that allows the highest ranking members to claim the best lands for agriculture (Park 1992). The best land changes on a yearly basis as it is dependent on the unpredictable flooding of the river. Poor years when the lowest members of the group do not have access to flooded land causes economic stratification as those individuals turn to a new subsistence base (Park 1992). This has been

[1] At the time of submission of this thesis, results from radiocarbon dates from human bone samples from each cemetery were pending.

shown for ancient Egypt (Park 1992) as well and is also the case for the Wari Middle Horizon in the lower Ica Valley. However, the variability in conditions seen in south coast data, or indeed in any arid environment, means that applying generalised models over a large area could actually be misleading as the local variation in micro environment can make substantial differences in arid regions (Hassan 2002; Kinahan 2000; Newson 2000). Thus any investigations of human-landscape interactions in desert environments need to consider micro events as well as the macro level changes.

Chapter 10 Conclusions

This chapter summarises the findings of this research. It examines the extent to which the methods used in this research - both practical and theoretical - were successful. Finally, the future directions for research stemming from this thesis are detailed.

10.1 Research Aims

In Chapter 1, I proposed to address the four cultural periods through a series of smaller questions, which would feed into larger hypotheses about the lower Ica Valley and the south coast region.

These more focused questions allowed me to frame the larger research questions around basic ideas of what foods were consumed and how diet reflected social and economic practices at the individual level. Whilst the lack of contextual information made it difficult to confidently conclude certain points, this approach facilitated the exploration of the larger questions and hypotheses set. The data used in this research did not fully support all of the hypotheses made in Chapter 1. Given that these stances were based on the available published research, it demonstrates that our knowledge and understanding of the lower Ica Valley and south coast archaeology are still expanding.

This research has built a model of gradual dietary change over 1500 years, with maize becoming the dominant resource in the Late Intermediate Period. In the Early Horizon, a mixed economic subsistence strategy was practised, with both wild and domesticated food resources consumed. The dietary components came from a wide range of possible resources - the coast, *lomas*, riparian woodland and cultivated land. This breadth, which was seemingly not related to any social divisions, is likely a reflection on the social organisation that operated in the lower valley at this time. Here, unlike in the middle Ica Valley, the people did not appear to be fully incorporated into the agricultural and political dynamics of the Callango and Ocucaje basins, or if they were, it is not obvious in the isotopic record.

Moving through time to the Early Intermediate Period, the Late Nasca data present a homogenous group in terms of dietary resources consumed, with no indication of the social complexity seen in the iconographic record of the same period. The data suggest that the Nasca were still practising agriculture with few discernible effects of the declining

environmental conditions visible in their dietary history. The use of wild resources as hypothesised elsewhere cannot be ruled out using these data. Taking a broader view of the adoption and reliance on maize, the slow take up of the crop and continued use of wild resources does seem to be a common trend in the Americas. The Late Nasca data from the lower Ica Valley support the ideas of this late cultural phase as a time of weak centralisation of local units, which were still united by a shared cultural tradition. Competition for the most productive lands may have occurred in some areas and it is at the macro level that dietary differences are most clear, reflecting the variability in the environment across the region.

The Middle Horizon period that follows has proven, in some ways, to be the most interesting period in this research, producing new ideas about how the Wari empire was represented and co-operated with the local hinterland population. From dietary information alone, I have identified different social groupings in the adult population, likely to be highland elites, local elites, long-distance traders, as well as a juvenile population who stood apart from the adults in terms of diet. The interpretation of these groups has led to the hypothesis that Wari highland elites permanently resided in the lower Ica Valley, alongside local elites, which has not been proposed before in the published literature. The evidence for traders reinforces the idea of the exploitation of this region for cotton needed by the state for the production of textiles. Food was clearly used here to make meaningful distinctions among different groups both in the way that it was acquired and what was consumed. This hypothesis also suggests that the lower Ica Valley was still habitable and productive at this time, despite an apparent dearth of domesticates in the archaeobotanical record. This discrepancy is in part a reflection on the limited work that has been carried out in the valley as well as a reflection in the lack of temporal resolution, as archaeology in the region is all too reliant on a ceramic sequence which has very few secure radiocarbon dates associated to it.

Finally, the Late Intermediate Period in the lower Ica Valley has been neglected in the archaeological record in comparison to the preceding periods. My research supports the idea that the Ica Valley was organised like the powerful, centralised Chincha Valley to the north, although on a smaller scale. Both horizontal and vertical movements of people and foods in the landscape are visible through the isotopic records and suggest trading of coastal resources to the highlands, as has been suggested for the Chincha based on ethnohistorical sources. However, this research has proposed that the Ica Valley operated on a smaller scale, perhaps with a unified socio-political group only occurring in the lower to middle valley, and then another, with whom they co-operated, inhabiting the upper valley. The use of food for

creating and maintaining social distinctions is unclear during this period, and even the published data do not seem to show consensus on how social distinctions were maintained. However, this research does show that the lower Ica Valley resident population consumed primarily a maize based diet, which indicates a significant improvement in the environmental conditions from the Middle Horizon some 200 years or so earlier. An unanswered question stemming from this research: is when did this landscape become void of habitation and largely denuded of vegetation as it appears today?

This research contributes significantly to current debates present in south coast archaeology. By investigating populations outside of the core research area (the Río Grande drainage), I have been able to show that there are similarities and differences within the south coast sphere. Patterns are applicable over a wide area but a much more nuanced view is obtained when local conditions - the landscape, natural resources, distance from others, individual actions - are taken into account. This research has provided new insights into the socio-economic organisation of the periods studied, as well as over a longer time frame as it is the only south coast isotopic study to have spanned from the Early Horizon to the Late Intermediate Period. Stepping further back, this research adds to the body of literature concerned with the nature of human occupation in desert environments, and although local environmental variation will contribute a lot to human behaviour, it is clear that food can but does not necessarily have to be used as a tool for social manipulation of situations.

This research also sought to use a new approach by using multiple tissues in order to ascertain individual life histories. This methodology has proven to be extremely successful in this research. Individual dietary changes have been seen and thanks to the different periods of life represented by each tissue it has been possible to give approximate ages or life stages when dietary transitions took place. This development has profound implications for the way in which individual actions can be studied in the past. As the data come directly from the individuals they accurately reflect and represent one aspect of life that can be used to comment on both social and economic practices, which as demonstrated in this thesis, can be related to wider social or economic issues. The ability to reconstruct individual actions through palaeodietary reconstruction is arguably the most important contribution of this thesis. Whilst it has used four tissue types not necessarily available to all archaeologists it

does suggest that multiple tissues, as long as they represent different and preferably distinct life phases, can be used to reconstruct individual lived lives.

10.2 Research Purpose

This research proposed three mechanisms as its basis, one theoretical, one practical and the other methodological. In this section I shall review how well these worked.

1) Theoretical - From the micro to macro scale using food

The use of food to bridge the gap between the social and biological aspects of life and to take these from the basic quotidian level to the higher macro structures has, in my opinion, worked well here. I have not only been able to look at small issues - what did people eat, did they move about the landscape - but also larger issues, such as economic practices and relationships between the lower Ica Valley and larger social units. The existence of botanical and environmental data for the lower Ica Valley meant I was able to address fully both the biological and social factors that may have impacted on dietary choices in the past, although at times the accuracy of the botanical data came into question as it did not marry well to the social interpretation.

2) Practical - Using looted remains

By carefully sampling the looted remains, I was able to achieve a high success rate in terms of useable collagen or keratin samples. This research has aptly demonstrated that looted human and faunal remains can be of value to the archaeologist and contribute greatly to our understanding of cultures. This insight is not only applicable on the south coast of Peru but in any region where looting occurs and especially in dry environments, where preservation is arguably greater than in other burial conditions.

3) Methodological - Using multiple tissue samples together

The use of the four different tissue types enabled me to identify trends and social divisions that otherwise would have not been visible through the use of just one tissue and that have not been identified by other researchers using stable isotopes on the south coast. It furnished a much greater resolution at the life history level and thus was very useful in exploring how people interacted with their landscape. This research has demonstrated that social issues and the ability to identify individual actions can be answered using stable isotope analysis.

Furthermore the use of ecological modelling as a tool for interpreting the multiple strands of isotopic data was very effective for the Middle Horizon data, and thus has potential in isotopic studies globally. The use of multiple tissues in this research also has methodological implications for isotope studies across all archaeological time periods and geographical areas. The examination of the relationship between the isotopic values of different tissues and the discrepancies and potential inadequacies of our current offset models has been clearly shown and highlights the need for further work and more cautionary interpretations in the meantime.

10.3 Future Directions

Several interesting and unresolved avenues of research have emerged from this thesis, which merit further investigation.

Extension of Sample Area Along the Ica Valley

This research has looked at the relationship between the people of the lower valley and the rest of the wider south coast area. Several interesting points have been raised about differences between the Ica Valley basins in earliest period as well as the movement of people through the valley in the later periods. By expanding the analysis to other areas of the Ica Valley, such as the Callango and Ocucaje basins, a better understanding could be attained of how the whole valley changed, with the movement of people, foods and ideas. Additionally larger sample sizes ought to lead to more meaningful interpretations.

Carbonate Analysis of Samples to Examine Whole Diet

$\delta^{13}C$ analysis of bone and/or tooth carbonate to examine whole diet can provide another view into the dietary history of an individual. In combination with $\delta^{13}C$ analysis of collagen it can be used to attain a more detailed understanding of the dietary components and has been used to good effect in Andean research (e.g. Slovak and Paytan 2011; Turner *et al.* 2010). This is done through the application of mixing models (e.g. Kellner and Schoeninger 2007), which allow the researcher to estimate the proportion and type (C_3 or C_4) or both carbohydrates and proteins in the diet. It would be especially useful in the Early Horizon to Middle Horizon datasets where it is unclear if the C_4 signal in the tissues is from direct consumption of a C_4 plant (maize), a carbohydrate, or, whether it has been incorporated indirectly through eating a animal (a source of protein) with a C_4 signal.

Oxygen and/or Strontium Analysis to Examine Mobility

$\delta^{18}O$ or $^{87}Sr/^{86}Sr$ analysis of bone and/or tooth carbonate, or indeed hair samples, would be useful in shedding light on the movement of the people. The large altitudinal range of the Andes makes oxygen isotopes analysis a particularly promising area for research (Knudson 2009), as does the variation in geology for strontium isotope analysis. On their own, or in combination, this type of isotopic data would enhance the exploration of human-landscape interactions through the angle of mobility. Use of oxygen isotope analysis along the length of the hair could be used to investigate movement at the seasonal level and thus provide information on whether the individuals with high carbon and nitrogen isotopic variation along the length of their hair had to travel to their food or if their food was moved to the lower Ica Valley.

Exploration of the Middle Horizon Social Groupings

Whilst all of the time periods studied here have proven interesting in their own right, in my opinion, the Wari data raise questions that could be approached through further isotopic analysis. The presence of several groups with multiple subsistence strategies and evidence for movement in the landscape, provides ample reasons to apply strontium, oxygen or hydrogen isotope analysis that can be used to track movement at different timescales, depending on the tissue used. Again, using multiple tissues for this type of analysis would be useful in revealing any movement between childhood and adulthood. Analysis of this type along the length of the hair would be useful for investigating the individuals mooted as long distance traders. This type of analyses would also necessitate the isotopic characterisation of the Ica Valley and the wider south coast region in order to contextualise the results from the humans, which in itself would have a larger impact on the interpretation of isotopic analyses carried out across the south coast.

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DATE: CEMETERY: INDIVIDUAL: LOCATION:

BONE SAMPLE NO.: ELEMENT/SIDE:

HAIR SAMPLE NO.: SAMPLE LOCATION:

APPROX. LENGTH: CONDITION:

NOTES:

SEX: Cranial Morphology

General size		Zygomatics		Standards 5 pt.	
Architecture		Arcade of maxilla		Nuchal crest	
Frontal bossing		Occipital condyle		Supraorbital marg	
Parietal bossing		Mandible		Mastoid process	
Orbit shape		Gonial angle		Glabella	
Forehead		Gonial flare		Mental eminence	

AGE: Dentition

	Mandibular	Maxillary
Lovejoy (1985)		
Brothwell (1981)		

DENTAL SAMPLE NO.: TOOTH/SIDE:

NOTES:

AGE: Cranial Sutures (Meindl & Lovejoy 1985)

Site - Vault	Score	Site - Lat.-ant.	Score
Midlambdoid		Midcoronal	
Lambda		Pterion	
Obelion		Sphenofrontal	
Anterior sagittal		Inferior sphenotemporal	
Bregma		Superior sphenotemporal	
Midcoronal			
Pterion			

SKIN SAMPLE NO.: SAMPLE LOCATION:

APPROX. SIZE: CONDITION:

NOTES:

NOTES:

PHOTOS:

PERU 2010 ADULT CRANIAL

DATE: CEMETERY: INDIVIDUAL: LOCATION:

BONE SAMPLE NO.: ELEMENT/SIDE:

SEX: ADULT Pelvic Morphology

General morph.		Ishiopubic ramus		Obturator foramen	
Pelvic inlet		Ilium		Acetabulum	
Subpubic angle		Sacrum			
Ventral arc		Auricular surface		Standards 5 pt.	
Subpubic concavity		Length of pubic bone		Greater sciatic notch	
				Preauricular sulcus	

AGE: ADULT Pubic Symphysis (Suchey-Brooks 1990)

Side	
Phase	

AGE: ADULT Auricular Surface

Buckberry-Chamberlain (2002)		Lovejoy et al. (1985)	
Transverse org.		Phase	
Surface texture		Age	
Microporosity			
Macroporosity			
Apical changes			
Composite score			
Age			

NOTES:

SEX: JUVENILE Pelvic Morphology

Sciatic notch angle		Arc criterion	
Sciatic notch depth		Iliac crest curvature	

AGE: JUVENILE Pelvic Fusion

Ischium and pubis fuse	
Ilium ischium and pubis unite	
Ischial epiphysis fuses	
Iliac crest to hip bone	

NOTES:

SKIN SAMPLE NO.: SAMPLE LOCATION:

APPROX. SIZE: CONDITION:

NOTES:

PHOTOS:

PERU 2010 ADULT/JUVENILE PELVIC

DATE: CEMETERY: INDIVIDUAL: LOCATION:

BONE SAMPLE NO.: ELEMENT/SIDE:

HAIR SAMPLE NO.: SAMPLE LOCATION:

APPROX. LENGTH: CONDITION:

NOTES:

SEX: Cranial Morphology

Mental eminenece		Dental front row	
Gonial eversion			

AGE: Dentition

	Mandibular	Maxillary
Ubelaker (1989)		

NOTES:

SKIN SAMPLE NO.: SAMPLE LOCATION:

APPROX. SIZE: CONDITION:

NOTES:

DENTAL SAMPLE NO.: TOOTH/SIDE:

NOTES:

PHOTOS:

PERU 2010 JUVENILE CRANIAL

Appendix 2 Osteological and Pathological Information for Each Individual

Key to Sex Codes:

J = Juvenile
F = Female
F? = Probable female
M = Male
M? = Probable Male
U = Unknown

Key to Age Codes:

FO = Foetus
EC = Early childhood
LC = Late childhood
ADOL = Adolescent
<18 years = Juvenile, specific age range unknown
YA = Young adult
YMA = Young middle adult
OMA = Old middle adult
MA = Mature adult
Adult = Adult, specific age range unknown
U = Unknown

Key to Pathology Code:

AMTL = Ante-mortem tooth loss
L5 = Fifth lumbar vertebra
OA = Osteoarthritis
M3 = 3rd molar tooth
? = indicates pathology is only tentatively identified

Cemetery 1001 - Early Horizon				
Individual	**Cemetery Sector**	**Sex**	**Age**	**Osteological and Pathological Notes**
1	A	F	YA	Caries
2	A	U	U	
54	A	U	OMA	AMTL (5), abscess
55	A	F	YA	Circumferential deformation
56	A	J	EC	
57	A	M	MA	AMTL (14), degenerative joint disease
58	A	J	EC	
59	A	U	U	
Cemetery 1002 - Early Horizon				
Individual	**Sex**	**Age**		**Osteological and Pathological Notes**

Table continued...

3	J	EC	
4	J	EC	
5	J	<18 years	
111	F	Adult	
112	F?	Adult	L5 sacralisation
113	U	Adult	
114	J	FO	
115	J	EC	
116	U	Adult	
117	F?	MA	
118	M?	OMA	AMTL (5), periodontal disease, enthesophytes

Cemetery 1004 - Early Horizon

Individual	Cemetery Sector	Sex	Age	Osteological and Pathological Notes
6	B	U	YA	Healed rib fracture
60	A	F?	Adult	Vertebral osteophytes
61	A	U	Adult	
62	A	U	Adult	
63	B	U	OMA	
64	B	U	Adult	
65	B	J	EC	
66	B	F	YMA	Carious lesion
67	B	F	MA	Vertebral osteophytes
68	C	M	OMA	Kyphosis, AMTL (3), abscess (5)
69	C	M?	YA	
70	E	F	OMA	Vertebral OA and osteophytes
71	E	J	EC	
72	E	U	Adult	Vertebral osteophytes

Cemetery 734 - Early Intermediate Period

Individual	Cemetery Sector	Sex	Age	Osteological and Pathological Notes
8	A	J	EC	
9	A	F?	YMA	AMTL (4), caries (2)
10	A	U	Adult	
11	A	U	Adult	
12	A	U	Adult	Bilateral periostisis on femora
13	A	J	LC	
14	A	U	Adult	
15	A	U	Adult	Cortical defect on femur
16	A	M?	YA	
17	A	J	EC	Nit eggs in hair
18	A	F	OMA	
103	A	M	OMA	AMTL (2), abscess?
104	A	J	EC	Maxillary sinusitis
105	A	M?	OMA	AMTL, cranial deformation

Table continued...

106	A	M?	Adult	Bilobial cranial deformation, porotic hyperostosis
107	A	U	Adult	Nit eggs in hair
108	A	J	EC	
109	A	M?	OMA	AMTL (3), abscess, calculus, impacted M3, extra bony projection on occipital
110	A	M	YMA	Bilobial cranial deformation, retained metopic suture

Cemetery 398 - Middle Horizon			
Individual	**Sex**	**Age**	**Osteological and Pathological Notes**
24	M?	MA	AMTL (2), abscess (9), caries (3)
25	M	Adult	Nit eggs in hair, AMTL (7), abscess?
26	F	MA	Unusual wear on 2 teeth, periodontal disease?, carious lesion, calculus
27	F	Adult	AMTL (7), abscess (3), caries
34	U	U	
89	J	EC	
90	F?	OMA	Caries (3), abscess, AMTL, broken crown on tooth?
91	M?	OMA	Asymmetrical occipital condyles, caries (4), abscess (2), AMTL (5)
92	M	OMA	Carious lesion, abscess (2), broken crown on tooth?
93	M	MA	AMTL (15)
94	M	YA	Calculus, abscess, crowded dentition
95	M	OMA	Caries (3)
96	F	YA	
97	M?	YMA	Caries (2), crowded dentition
98	M	OMA	Abscess (2), AMTL (4), caries (2), asymmetrical mastoid processes
99	F	YMA	AMTL (1, possibly 2?), abscess
100	J	LC	Cribra orbitalia
101	U	YMA	Carious lesion
102	J	ADOL	

Cemetery 755 - Middle Horizon			
Individual	**Sex**	**Age**	**Osteological and Pathological Notes**
19	M?	OMA	Bilobial cranial deformation, caries (4)
20	J	EC	Cribra orbitalia
21	M?	YA	Calculus?
22	M	YA	Healed cribra orbitalia, caries (2)
23	J	EC	
33	U	U	
35	U	U	
48	J	EC	Supernumerary tooth, calculus
49	U	OMA	
50	J	LC	Caries (3), ectocranial lesion, new bone formation (periostitis?)
51	J	ADOL	Carious lesion, calculus, maxillary sinusitis

Table continued...

52	M	OMA	Cranial enthesophytes, AMTL (4), carious lesion, periodontal disease
53	M?	YMA	Carious lesion, calculus, asymmetrical foramen magnum
81	F?	OMA	Periodontal disease?
82	J	LC	
83	F?	YMA	Caries (7), calculus, button osteoma (2), asymmetrical orbits
84	J	LC	Cribra orbitalia
85	M	MA	Caries (3), calculus
86	M	YMA	AMTL (3), abscess (2), carious lesion
87	F?	YMA	AMTL (2)
88	M	OMA	Calculus, periodontal disease

Cemetery 1003 - Late Intermediate Period				
Individual	**Cemetery Sector**	**Sex**	**Age**	**Osteological and Pathological Notes**
28	B	F?	YMA	Red staining on face
29	B	J	LC	Calculus
30	B	M?	Adult	AMTL (3), abscess, linear enamel hypoplasia
31	B	M	OMA	Carious lesion, periodontal disease, uneven tooth wear
32	B	F?	ADOL	Calculus, caries (2)
36	B	M	YMA	Caries (3), periodontal disease, calculus, extra condylar facet, red and green staining
37	B	M	MA	AMTL (12), abscess (4), nit eggs in hair
38	B	M?	YMA	AMTL (3), caries (4), button osteoma, ectocranial lesions (3)
39	B	F?	YMA	AMTL?, red staining on face
40	B	J	EC	
41	B	F?	YA	
42	B	J	<18 years	
43	B	M	OMA	Calculus, periodontal disease, ectocranial lesion
44	B	J	LC	Carious lesion
45	B	M	YMA	AMTL (3), abscess (3)
46	B	F?	MA	Temporo-mandibular arthritis
47	B	U	Adult	Vertebral OA, AMTL (14), red staining on face
73	B	M?	YMA	
74	B	F	YA	Carious lesion
75	B	U	OMA	AMTL (2), abscess (2), nit eggs
76	B	F?	OMA	AMTL (3), caries (2), calculus, plagiocephaly
77	B	U	U	
78	B	J	LC	Carious lesion, cribra orbitalia
79	B	M	OMA	Red staining on face, cribra orbitalia
80	B	M	YMA	AMTL (2), abscess, supernumerary tooth
119	B	F	YMA	Caries (2), abscess, dislocated and OA at false

Table continued...

				joint of temporo-mandibular articulation
120	B	F?	YA	
121	B	J	LC	Cribra orbitalia

Appendix 3 Isotopic Results for All Individuals

Values given in bold indicate that the sample was of bad quality and discarded from the main analysis. $\delta^{13}C$ and $\delta^{15}N$ hair isotopic values that are in bold failed based on their amplitude, whereas those samples with the C:N ratio in bold did not produce an acceptable ratio.

Cemetery 1001 - Early Horizon												
Individual	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**Standard Deviation**	**Mean $\delta^{15}N$ (‰)**	**Standard Deviation**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Hair segmented?**	**Notes**
1	Bone	-16.9	0.0	11.9	0.1	3	3.44	20.0	Mandible			
	Tooth	-16.6	0.1	11.3	0.0	3	3.23	16.0		LLM2		
2	**Hair**	**-18.2**	**0.1**	**6.9**	**0.5**	3	3.85				N	Failed on amplitude
54	Bone	-17.5	0.1	9.2	0.1	3	3.53	9.5	Skull			
	Tooth	-18.5	0.3	10.4	0.0	3	**4.25**	10.4		URM3		
	Hair	-17.7	0.1	8.9	0.1	3	3.80				N	
55	Bone	-16.9	0.0	11.7	0.1	3	3.45	16.7	Skull			
	Tooth	-16.5	0.0	11.8	0.1	3	3.25	16.7		URM2		
	Hair	-17.4	0.2	11.0	0.5	3	3.71				N	
56	Bone	-17.0	0.0	12.9	0.1	3	3.54	4.0	Ischium			
57	Bone	-17.3	0.1	9.4	0.0	3	3.47	12.8	Fibula			
58	Bone	-16.0	0.0	11.7	0.1	3	3.23	7.1	Femur			
59	**Hair**	**-16.6**	**0.5**	**11.7**	**1.1**	14	3.57				Y	Run failed based on standard. Insufficient sample to re-run.
Cemetery 1002 - Early Horizon												
Individual	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**Standard Deviation**	**Mean $\delta^{15}N$ (‰)**	**Standard Deviation**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Hair segmented?**	**Notes**
3	Bone	-13.1	0.2	8.9	0.1	3	3.29	1.0	Femur			
4	Tooth									ULdM2		Not run as deciduous
5	**Bone**							**1.3**	Skull			Bone not run as yield too low/poor collagen produced
	Hair	-13.9	0.3	10.9	0.0	2	**4.32**				N	
111	Bone	-17.0	0.0	6.8	0.1	3	3.20	22.1	Femur			

Table continued...

112	**Bone**							**1.4**	Femur			Not run as yield too low/poor collagen produced
113	**Bone**							**1.4**	Radius			Not run as yield too low/poor collagen produced
114	**Bone**							**0**	Femur			Not run as yield too low/poor collagen produced
115	Bone	-16.3	0.0	9.7	0.1	3	3.21	19.7	Femur			
116	Bone	-16.2	0.1	10.3	0.1	3	3.16	10.4	Fibula			
117	Bone	-16.5	0.1	8.3	0.1	3	3.22	20.9	Acetabulum			
118	Bone	-13.7	0.1	10.7	0.1	3	3.25	19.7	Mandible			
	Tooth	-14.7	0.1	10.4	0.1	3	3.20	14.4		LLM3		
	Skin	-13.7	0.1	12.2	0.0	3	3.38	30.8				
Cemetery 1004 - Early Horizon												
Individual	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**Standard Deviation**	**Mean $\delta^{15}N$ (‰)**	**Standard Deviation**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Hair segmented?**	**Notes**
6	Bone	-16.5	0.0	12.8	0.1	3	3.31	15.2	Rib			
60	**Bone**	-17.6	0.1	9.4	0.0	3	**4.53**	12.9	Femur			
61	Bone	-16.1	0.0	8.3	0.1	3	3.47	20.6	Fibula			
62	Bone	-16.9	0.1	9.6	0.1	3	3.59	15.1	Tibia			
63	Bone	-14.2	0.0	10.1	0.0	3	3.35	16.4	Ulna			
64	Bone	-15.3	0.0	10.2	0.0	3	3.19	14.9	Humerus			
65	Bone	-15.7	0.0	9.8	0.0	3	3.36	16.2	Humerus			
66	Bone	-15.8	0.1	8.1	0.1	3	3.39	23.1	Tibia			
	Tooth	-16.2	0.1	8.7	0.0	3	3.42	18.1		LRM1		
67	**Bone**	-16.1	0.1	9.4	0.1	3	**3.88**	23.1	Femur			
	Hair	-16.2	0.7	8.8	0.9	7	3.79					
68	Bone	-16.5	0.0	10.7	0.1	3	3.36	16.5	Skull			
	Tooth	-16.4	0.1	10.4	0.1	3	3.18	14.9		LLM1		

Table continued...

	Hair	-17.7	0.1	10.5	0.2	3	3.72					
69	Bone	-15.7	0.0	8.5	0.1	3	3.26	21.3	Humerus			
	Tooth	-15.5	0.1	10.2	0.0	3	3.18	17.0		ULM3		
	Hair	-16.4	0.4	9.4	0.3	8	3.67				Y	
70	Bone	-16.8	0.0	7.3	0.1	3	3.48	21.4	Tibia			
71	Bone	-13.6	0.1	9.3	0.1	3	3.24	23.3	Vertebra			
72	**Bone**	-16.6	0.0	10.3	0.0	3	**3.76**	21	Vertebra			
Cemetery 734 - Early Intermediate Period												
Individual	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**Standard Deviation**	**Mean $\delta^{15}N$ (‰)**	**Standard Deviation**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Hair segmented?**	**Notes**
8	Bone	-15.8	0.0	8.9	0.0	3	3.19	20.1	Skull			Tooth not run as deciduous
	Tooth									ULdM2		
9	Bone	-14.2	0.0	8.8	0.1	3	3.18	18.6	Mandible			
	Tooth	-15.2	0.1	8.3	0.0	3	3.20	17.9		LLM2		
10	Bone	-15.5	0.1	9.0	0.0	3	3.13	18.7	Femur			
11	Bone	-13.8	0.0	9.4	0.0	3	3.17	19.3	Femur			
12	Bone	-15.6	0.0	9.8	0.0	3	3.17	18.3	Femur			
13	Bone	-15.3	0.0	9.7	0.1	3	3.17	23.4	Tibia			
14	Bone	-15.3	0.0	9.1	0.1	3	3.16	23.9	Femur			
15	Bone	-15.4	0.0	9.7	0.1	3	3.16	22.6	Femur			
16	Bone	-14.5	0.0	8.3	0.0	3	3.16	21.2	Os coxae			
17	Bone	-14.7	0.0	8.9	0.0	3	3.17	23.1	Skull			Tooth apices not closed
	Tooth	-16.5	0.0	8.7	0.0	3	3.17	19.7		URM1		
	Hair	-17.7	0.5	6.9	0.8	7	3.56				Y	
18	Bone	-14.0	0.1	8.5	0.0	3	3.24	14.4	Os coxae			
103	Bone	-13.7	0.0	9.4	0.0	3	3.19	19.2	Mandible			
	Tooth	-13.3	0.1	10.4	0.0	3	3.14	19.1		LRM3		
104	**Bone**	-17.3	0.1	13.5	0.1	3	**3.92**	1.5	Skull			

Table continued...

	Hair	-17.2	0.0	10.8	0.1	2	3.50				N	
105	Bone	-14.2	0.0	10.0	0.1	3	3.23	20.6	Skull			
106	Bone	-16.2	0.0	9.9	0.1	3	3.27	22.2	Skull			
107	Hair	-15.8	0.3	7.3	0.3	12	3.63				Y	
108	Bone	-13.3	0.0	12.0	0.1	3	3.19	22.2	Skull			
	Hair	-15.2	0.2	11.5	0.0	3	3.56					
109	Bone	-14.4	0.0	8.5	0.1	3	3.16	21.1	Skull			
	Tooth	-14.7	0.1	8.6	0.0	3	3.14	15.7		ULM2		
110	Bone	-15.0	0.1	6.9	0.0	3	3.19	20.2	Skull			
	Tooth	-14.3	0.1	7.7	0.0	3	3.16	14.5		ULM2		
Cemetery 398 - Middle Horizon												
Individual	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**Standard Deviation**	**Mean $\delta^{15}N$ (‰)**	**Standard Deviation**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Hair segmented?**	**Notes**
24	Bone	-13.2	0.0	10.0	0.0	3	3.22	21.1	Skull			
	Tooth	-15.8	0.1	9.7	0.1	3	3.20	16.8		URM1		
	Hair	-11.7	0.3	9.4	0.4	15	3.84				Y	
25	Bone	-13.0	0.1	10.6	0.0	3	3.22	19.9	Skull			
	Skin	-13.5	0.1	13.1	0.0	3	3.60	33.3				
	Hair	-12.7	0.5	9.5	0.2	16	3.58				Y	
26	Bone	-13.0	0.0	9.8	0.0	3	3.21	20.8	Skull			
	Tooth	-15.5	0.0	9.6	0.1	3	3.16	18.3		ULM2		
	Skin	-14.3	0.1	11.4	0.1	3	3.34	50.0				
	Hair	-13.8	0.4	7.7	0.3	17	3.61				Y	
27	Bone	-12.6	0.0	9.1	0.0	3	3.15	19.4	Skull			
	Tooth	-12.6	0.1	10.1	0.0	3	3.16	18.5		ULM3		
	Skin	-13.5	0.1	12.1	0.0	3	3.35	46.4				
	Hair	-12.9	1.4	9.0	1.0	10	3.69				Y	
34	Hair	-14.7	0.5	8.9	0.2	31	3.67				Y	Values for main plait given

Table continued...

												here, see Appendix 4 for extension values and Appendix 6 about construction of plait
89	Bone	-15.7	0.0	10.4	0.0	3	3.22	27.5	Skull			Tooth apices not closed
	Tooth	-15.7	0.0	10.7	0.0	3	3.15	20.6		URM1		
	Skin	-14.4	0.0	12.5	0.1	3	3.38	37.9				
	Hair	-16.7	0.4	9.1	0.2	6	3.66				Y	
90	Bone	-11.9	0.2	8.4	0.1	3	3.28	23.6	Skull			
	Tooth	-11.9	0.1	9.2	0.0	3	3.21	20.4		ULM2		
	Hair	-12.4	1.1	8.0	0.5	8	3.81				Y	
91	Bone	-13.4	0.0	9.7	0.1	3	3.15	20.1	Skull			
	Tooth	-14.0	0.0	10.4	0.0	3	3.16	18.1		URM2		
	Hair	-15.9	0.3	8.4	0.1	3	3.45				N	
92	Bone	-13.5	0.0	9.9	0.0	3	3.18	20.3	Skull			
	Tooth	-14.7	0.1	9.9	0.0	3	3.17	18.6		URM2		
93	Bone	-10.6	0.0	9.6	0.1	3	3.30	23.2	Skull			
	Tooth	-10.8	0.0	9.8	0.1	3	3.23	20.6		ULM2		
	Hair	-13.1	0.5	7.0	0.3	6	3.74				Y	
94	Bone	-13.3	0.1	9.4	0.1	3	3.23	24.7	Skull			
	Tooth	-14.0	0.1	9.8	0.0	3	3.20	19.5		URM2		
	Hair	-11.1	0.6	10.1	0.5	23	3.74				Y	
95	Bone	-14.8	0.0	8.2	0.1	3	3.36	25.0	Skull			
	Tooth	-14.8	0.1	7.4	0.0	3	3.13	18.3		URM2		
96	Bone	-15.7	0.1	9.7	0.1	3	3.22	27.3	Skull			
	Tooth	-15.2	0.1	10.3	0.0	3	3.14	16.6		ULM1		
	Hair	-15.2	0.3	10.4	0.1	3	3.54				N	
97	Bone	-12.5	0.0	10.1	0.1	3	3.24	24.7	Skull			
	Tooth	-12.3	0.1	9.9	0.1	3	3.20	20.3		URM2		

Table continued...

	Hair	-14.7	0.4	11.9	0.1	2	3.68				N	
98	Bone	-14.3	0.1	9.9	0.1	3	3.17	21.9	Skull			
	Tooth	-15.0	0.1	10.4	0.0	3	3.15	16.1		URM2		
	Hair	-14.1	0.3	8.8	0.3	13	3.72				Y	
99	Bone	-14.9	0.0	9.3	0.1	3	3.22	25.0	Skull			
	Tooth	-15.8	0.1	9.3	0.0	3	3.13	17.4		ULM1		
	Hair	-15.4	0.3	7.5	0.3	11	3.62				Y	
100	Bone	-15.4	0.0	8.5	0.0	3	3.21	21.7	Skull			Tooth apices not closed
	Tooth	-15.4	0.0	9.2	0.0	3	3.16	19.3		URM1		
	Hair	-16.2	0.3	8.2	0.3	9	3.53				Y	
101	Bone	-13.7	0.0	9.5	0.0	3	3.17	19.5	Skull			
	Tooth	-13.6	0.1	9.9	0.1	3	3.15	18.6		URM2		
	Hair	-14.9	0.8	8.2	0.7	15	3.68				Y	
102	Bone	-13.5	0.1	9.6	0.1	3	3.18	26.3	Skull			
	Tooth	-14.9	0.0	10.8	0.0	3	3.14	19.3		URM1		
Cemetery 755 - Middle Horizon												
Individual	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**Standard Deviation**	**Mean $\delta^{15}N$ (‰)**	**Standard Deviation**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Hair segmented?**	**Notes**
19	Bone	-13.3	0.0	7.5	0.1	3	3.18	9.7	Skull			
	Tooth	-12.9	0.0	7.9	0.0	3	3.14	14.8		URM2		
	Hair	-15.4	0.1	8.3	0.1	3	**3.98**				N	
20	Bone	-15.9	0.0	9.0	0.1	2	3.17	23.3	Skull			Tooth not run as deciduous
	Tooth									URdM2		
	Skin	-15.3	0.1	11.5	0.1	3	3.28	50.9				
	Hair	-16.4	0.4	8.4	0.2	6	3.58				Y	
21	Bone	-12.9	0.0	10.5	0.0	3	3.19	22.2	Skull			
	Tooth	-14.3	0.1	10.4	0.0	3	3.15	19.8		ULM1		
	Skin	-12.4	0.1	13.1	0.0	3	3.30	32.9				

Table continued...

	Hair	-11.2	0.8	10.1	0.5	20	3.71				Y	
22	Bone	-12.9	0.1	11.0	0.1	3	3.16	21.8	Skull			
	Tooth	-14.1	0.0	10.7	0.1	3	3.20	17.2		LRM2		
	Skin	-13.7	0.0	14.0	0.0	3	3.54	40.9				
	Hair	-14.4	1.5	11.1	0.4	40	3.84				Y	
23	Bone	-13.8	0.0	9.7	0.0	3	3.20	23.3	Femur			
	Tooth									LRdM2		Tooth not run as deciduous
	Hair	-15.8	0.1	7.1	0.1	3	3.58				N	
33	Hair											Not run, too brittle
35	Hair	-16.1	0.2	8.0	0.2	16	3.77				Y	
48	Bone	-14.8	0.0	9.9	0.1	3	3.14	23.0	Skull			Tooth apices not closed
	Tooth	-15.1	0.1	10.2	0.1	3	3.13	19.3		ULM1		
	Hair	-15.6	0.1	9.1	0.1	3	3.52				N	
49	Bone	-9.3	0.0	10.0	0.1	3	3.12	19.5	Skull			
50	Bone	-11.2	0.0	8.8	0.0	3	3.15	21.5	Skull			Tooth apices not closed Hair sample failed based on standard results. Insufficient sample to re-run.
	Tooth	-11.0	0.0	9.1	0.0	3	3.14	16.9		ULM1		
	Hair	**-14.5**	**0.2**	**8.0**	**0.2**	2	3.67				N	
51	Bone	-16.4	0.0	8.8	0.1	3	3.10	22.0	Skull			
	Tooth	-16.7	0.0	9.1	0.0	3	3.13	18.9		ULM2		
52	Bone	-10.7	0.1	9.7	0.0	3	3.15	19.4	Skull			Tooth not suitable for analysis
	Tooth									URC		
53	Bone	-9.8	0.0	8.8	0.0	3	3.19	22.0	Skull			
	Tooth	-10.6	0.1	8.7	0.0	3	3.14	17.4		ULM2		
81	Bone	-10.9	0.0	9.4	0.0	3	3.18	22.8	Skull			
	Tooth	-11.8	0.0	9.6	0.0	3	3.16	18.1		URM2		
	Skin	-12.1	0.1	12.0	0.1	3	3.64	5.6				
	Hair	-11.3	0.7	9.7	0.6	9	3.65				Y	
82	Bone	-13.7	0.0	9.8	0.0	3	3.14	22.6	Skull			

Table continued...

	Tooth	-13.5	0.0	9.8	0.0	3	3.12	17.5		ULM1		
83	Bone	-13.2	0.0	8.3	0.0	3	3.24	16.5	Skull			
	Tooth	-13.0	0.1	9.3	0.0	3	3.16	19.8		URM2		
84	Bone	-17.1	0.0	9.6	0.1	3	3.09	19.2	Skull			Tooth apices not closed
	Tooth	-16.9	0.1	10.4	0.0	3	3.12	16.7		URM1		
85	Bone	-13.5	0.0	9.9	0.0	3	3.18	9.1	Skull			
	Tooth	-14.7	0.0	10.2	0.0	3	3.15	19.4		URM2		
	Hair	-13.2	0.3	9.5	0.2	5	3.64				Y	
86	Bone	-10.5	0.0	8.0	0.0	3	3.17	19.8	Skull			
	Tooth	-10.7	0.1	8.6	0.0	3	3.15	18.8		ULM2		
87	Bone	-10.4	0.0	9.0	0.1	3	3.16	23.8	Skull			Tooth not suitable for analysis
	Tooth									ULM2		
	Hair	-9.8	0.4	9.1	0.3	10	3.60				Y	
88	Bone	-10.4	0.0	9.3	0.1	3	3.13	19.3	Skull			
	Tooth	-10.9	0.0	9.0	0.1	3	3.13	18.8		URM2		
Cemetery 1003 - Late Intermediate Period												
Individual	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**Standard Deviation**	**Mean $\delta^{15}N$ (‰)**	**Standard Deviation**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Hair segmented?**	**Notes**
28	Bone	-10.6	0.1	11.1	0.0	3	3.20	22.5	Skull			
	Skin	-10.3	0.1	14.5	0.1	3	3.39	35.0				
	Hair	-12.4	0.2	9.4	0.3	16	3.50				Y	
29	Bone	-9.4	0.0	11.0	0.0	3	3.43	21.9	Skull			
	Tooth	-9.3	0.0	10.7	0.0	3	3.19	21.1		URM1		Tooth apices not closed
	Hair	-9.4		10.1		1	3.44				N	
30	Bone	-8.8	0.0	9.7	0.0	3	3.32	22.2	Skull			
	Tooth									URC		Tooth not suitable for analysis
	Hair	-9.1	1.0	9.4	0.9	13	3.64				Y	
31	Bone	-10.3	0.0	9.6	0.0	3	3.13	19.3	Skull			

Table continued...

	Tooth	-10.6	0.0	9.5	0.1	3	3.12	15.0		ULM2		
32	Bone	-15.3	0.0	9.1	0.1	3	3.14	22.2	Skull			Tooth apices not closed
	Tooth	-14.6	0.0	9.8	0.0	3	3.13	17.0		ULM2		
36	Bone	-10.0	0.1	9.5	0.1	3	3.19	20.7	Skull			
	Tooth	-10.0	0.0	10.0	0.0	3	3.19	16.7		ULM2		
	Skin	-9.2	0.1	13.2	0.1	3	3.34	38.3				
	Hair	-10.0	0.4	10.9	0.4	30	3.54				Y	
37	Bone	-10.3	0.1	11.3	0.0	3	3.25	19.9	Skull			Tooth not suitable for analysis
	Tooth									ULI2		
	Skin	-10.7	0.0	12.3	0.1	3	3.29	47.5				
	Hair	-12.3	0.7	13.4	1.0	7	3.5				Y	
38	Bone	-9.9	0.0	11.4	0.0	3	3.16	20.8	Skull			
	Tooth	-10.6	0.0	11.1	0.0	3	3.14	19.5		URM2		
39	Bone	-10.3	0.0	10.6	0.1	3	3.14	20.6	Skull			
	Tooth	-11.5	0.0	10.5	0.1	3	3.16	17.0		ULM1		
	Skin	-10.4	0.1	13.2	0.0	3	3.29	36.4				
	Hair	-12.4	0.2	9.6	0.2	19	3.60				Y	
40	Bone	-9.3	0.0	10.2	0.0	3	3.29	25.2	Skull			Tooth not suitable for analysis
	Tooth									URM1		
	Skin	-7.8	0.0	12.5	0.1	3	3.33	37.8				
	Hair	-10.6	0.2	9.4	0.2	8	3.5				Y	
41	Bone	-10.3	0.0	8.3	0.0	3	3.49	25.9	Skull			Tooth apices not closed
	Tooth	-10.4	0.0	8.4	0.0	3	3.37	21.9		LRM2		
	Skin	-9.9	0.1	10.8	0.0	3	3.49	32.3				
	Hair	-11.3	0.7	7.4	0.5	16	3.54				Y	
42	Bone	-10.3		8.3		1	3.48	23.2	Skull			
	Skin	-11.0	0.0	11.5	0.0	3	3.26	48.3				
	Hair	-13.3	0.6	7.7	0.2	11	3.53				Y	
43	Bone	-10.1	0.0	10.2	0.0	3	3.21	21.4	Skull			

Table continued...

	Tooth	-11.0	0.1	9.1	0.0	3	3.14	20.2		URM2		
44	Bone	-11.2	0.0	9.7	0.0	3	3.45	26.9	Skull			Tooth apices not closed
	Tooth	-11.3	0.1	9.9	0.1	3	3.30	19.2		URM1		
45	Bone	-11.8	0.0	10.6	0.0	3	3.29	21.5	Skull			
	Tooth	-11.8	0.0	11.1	0.1	3	3.24	19.4		URM3		
	Hair	-11.0	1.0	10.0	0.5	14	**4.04**				Y	
46	Bone	-9.9	0.3	10.1	0.0	3	3.24	20.5	Skull			
47	Bone	-9.7	0.0	12.3	0.0	3	3.19	20.7	Skull			
	Skin	-9.7	0.1	14.9	0.1	3	3.30	51.8				
	Hair	-12.3	0.2	10.0	0.3	21	3.64				Y	
73	Bone	-9.3	0.0	9.2	0.1	3	3.20	20.1	Skull			
	Tooth	-9.2	0.0	9.0	0.0	3	3.15	16.2		URM1		
	Hair	-10.5	0.3	9.2	0.1	2	3.76				N	
74	Bone	-10.1	0.0	9.4	0.0	3	3.23	19.4	Mandible			
	Tooth	-10.1	0.1	9.9	0.0	3	3.24	20.5		ULM3		Tooth apices not closed
	Hair	-10.5	0.9	8.6	0.5	13	3.61				Y	
75	Bone	-11.8	0.0	8.9	0.0	3	3.18	23.9	Skull			
	Skin	-11.4	0.1	11.8	0.1	3	3.31	37.7				
	Hair	-13.8	0.3	7.2	0.6	9	3.44				Y	
76	Bone	-11.4	0.0	9.8	0.0	3	3.19	20.4	Skull			
	Tooth	-10.2	0.0	9.8	0.0	3	3.15	17.5		URM2		
	Skin	-11.1	0.0	12.2	0.1	3	3.28	40.7				
	Hair	-13.5	0.4	8.3	0.4	18	3.56				Y	
77	Hair	-11.2	0.5	8.9	0.8	44	3.68				Y	
78	Bone	-10.8	0.1	9.6	0.1	3	3.20	23.3	Skull			
	Tooth	-10.6	0.0	11.4	0.0	3	3.22	23.2		URM1		Tooth apices not closed
	Hair	-11.7	0.2	9.4	0.8	7	3.43				Y	
79	Bone	-11.9	0.0	8.8	0.0	3	3.16	19.8	Skull			
	Tooth	-12.1	0.0	9.2	0.0	3	3.17	16.2		ULM2		

Table continued...

80	Bone	-9.3	0.0	9.5	0.0	3	3.23	23.4	Skull			
	Tooth	-10.5	0.1	8.7	0.0	3	3.16	15.8		URM2		
	Hair	-9.8	0.7	9.5	0.6	27	3.63				Y	
119	Bone	-11.6	0.0	8.4	0.0	3	3.14	20.1	Skull			
	Tooth	-13.2	0.2	9.5	0.0	3	3.17	16.7		ULM1		
120	Bone	-10.9	0.0	9.9	0.0	3	3.28	22.1	Skull			
	Hair	-11.9	0.8	9.4	0.7	18	3.78				Y	
121	Tooth	-9.8	0.0	9.6	0.0	3	3.16	22.8		ULM1		Tooth apices not closed
	Hair	-11.4	0.8	8.0	0.2	6	3.47				Y	

Appendix 4 Segmented Hair Isotopic Results

Where values are given in bold the sample was of unacceptable quality (either due to bad C:N ratio or amplitude) and therefore excluded from the main analysis. Values given in italics were accepted with caution.

Cemetery 1004 - Early Horizon					
Individual	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**C:N**	**Distance from scalp (cm)**	**Notes**
67a	-15.2	9.2	**3.97**	1	
67b	-15.5	9.2	**3.96**	2	
67c	-15.7	9.1	**3.92**	3	
67d	-15.9	9.1	**3.86**	4	
67e	-15.7	8.8	3.80	5	
67f	-15.8	7.8	3.75	6	
67g	-15.6	7.5	3.77	7	
67h	-15.4	8.5	3.78	8	
67i	-16.5	9.5	3.79	9	
67j	-17.3	9.7	3.81	10	
67k	-16.9	9.7	3.83	11	
67l	-16.4	9.6	**3.87**	12	
67m	-16.0	9.4	**3.90**	13	
67n	-15.8	9.1	**3.89**	14	
67o	-16.6	8.8	**3.91**	15	
67p	-16.4	8.8	**3.92**	16	
67q	-17.1	8.8	**3.94**	17	
69a	-17.5	8.6	3.65	1	
69b	-17.2	9.3	3.67	2	
69c	-16.7	9.5	3.67	3	
69d	-16.5	9.7	3.67	4	
69e	-16.5	9.5	3.69	5	
69f	-16.1	9.6	3.67	6	
69g	-16.1	9.3	3.68	7	
69h	-15.9	9.0	3.67	8	
69i	-16.1	8.9	3.65	9	
69j	-16.4	8.1	3.62	10	
Cemetery 734 - Early Intermediate Period					
Individual	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**C:N**	**Distance from scalp (cm)**	**Notes**
17a	-17.0	8.3	3.57	1	
17b	-17.3	7.4	3.53	2	
17c	-17.6	7.0	3.54	3	
17d	-17.8	6.7	3.55	4	
17e	-18.4	6.1	3.54	5	
17f	-18.0	6.2	3.56	6	

Table continued...

17g	-17.6	6.7	3.62	7	
17h	**-17.8**	**6.8**	3.69	8	Rejected based on amplitude
107a	-15.1	7.1	3.65	1	
107b	-15.2	7.3	3.63	2	
107c	-15.7	7.3	3.61	3	
107d	-16.1	7.2	3.61	4	
107e	-16.1	7.0	3.59	5	
107f	-16.1	7.1	3.60	6	
107g	-16.0	7.2	3.61	7	
107h	-15.9	7.5	3.62	8	
107i	-15.9	7.6	3.63	9	
107j	-15.7	8.0	3.63	10	
107k	-15.9	7.5	3.65	11	
107l	-16.0	7.0	3.68	12	
107m	**-15.8**	**6.8**	3.67	13	Rejected based on amplitude
Cemetery 398 - Middle Horizon					
Individual	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**C:N**	**Distance from scalp (cm)**	**Notes**
24a	-13.5	10.3	**4.17**	1	
24b	-12.3	10.3	**3.89**	2	
24c	-11.8	10.1	*3.85*	3	Accepted with caution
24d	-11.6	10.0	*3.86*	4	Accepted with caution
24e	-11.7	10.0	*3.86*	5	Accepted with caution
24f	-11.6	9.8	*3.87*	6	Accepted with caution
24g	-11.5	9.6	3.84	7	
24h	-11.3	9.5	3.82	8	
24i	-11.3	9.2	3.81	9	
24j	-11.8	9.0	*3.85*	10	Accepted with caution
24k	-12.1	9.1	*3.86*	11	Accepted with caution
24l	-12.2	9.0	*3.89*	12	Accepted with caution
24m	-12.5	9.2	**4.01**	13	
24n	-12.0	9.5	**4.06**	14	
24o	-11.4	9.4	**3.92**	15	
24p	-11.1	9.1	3.84	16	
24q	-11.3	9.1	3.80	17	
24r	-12.1	9.1	3.80	18	
24s	-12.1	9.3	3.84	19	
24t	-12.1	9.3	**3.93**	20	
24u	-11.7	9.1	**3.86**	21	
24v	-11.8	9.1	3.83	22	
24w	-11.4	9.9	**3.90**	23	
24x	-11.3	9.2	**3.99**	24	
24y	-11.1	9.8	**4.02**	25	
25a	-12.7	9.2	3.57	1	

Table continued...

25b	-12.4	9.3	3.54	2	
25c	-11.9	9.4	3.50	3	
25d	-11.8	9.5	3.51	4	
25e	-12.0	9.7	3.52	5	
25f	-12.2	9.7	3.51	6	
25g	-12.5	9.7	3.54	7	
25h	-13.0	9.6	3.54	8	
25i	-13.1	9.5	3.55	9	
25j	-13.3	9.5	3.57	10	
25k	-13.2	9.4	3.59	11	
25l	-12.8	9.5	3.62	12	
25m	-12.5	9.5	3.63	13	
25n	-13.0	9.3	3.67	14	
25o	-13.1	9.4	3.71	15	
25p	-12.8	9.6	3.72	16	
25q	**-12.9**	**9.7**	3.71	17	Rejected based on amplitude
26a	-13.3	8.4	3.63	1	
26b	-13.2	7.9	3.60	2	
26c	-13.7	7.6	3.60	3	
26d	-13.7	7.6	3.60	4	
26e	-13.9	7.6	3.60	5	
26f	-13.7	7.8	3.60	6	
26g	-13.4	8.0	3.61	7	
26h	-13.1	8.1	3.60	8	
26i	-13.1	8.1	3.61	9	
26j	-13.4	7.8	3.62	10	
26k	-13.8	7.7	3.61	11	
26l	-14.2	7.4	3.61	12	
26m	-14.4	7.3	3.61	13	
26n	-14.4	7.3	3.61	14	
26o	-14.3	7.4	3.63	15	
26p	-14.3	7.5	3.65	16	
26q	-13.9	7.7	3.61	17	
26r	**-14.1**	**7.6**	3.65	18	Rejected based on amplitude
26s	**-13.5**	**7.9**	3.70	19	Rejected based on amplitude
26t	**-13.6**	**7.4**	3.67	20	Rejected based on amplitude
26u	-15.1	6.8	**3.91**	21	
27a	-11.5	10.2	3.75	1	
27b	-11.3	10.3	3.72	2	
27c	-11.4	10.0	3.67	3	
27d	-11.8	9.6	3.68	4	
27e	-12.5	9.2	3.68	5	
27f	-12.8	8.9	3.65	6	
27g	-13.4	8.3	3.68	7	
27h	-14.6	7.7	3.67	8	

Table continued...

27i	-15.0	7.7	3.69	9	
27j	-14.5	8.1	3.70	10	
27k	**-14.0**	**8.3**	3.70	11	Rejected based on amplitude
27l	**-14.4**	**7.8**	3.78	12	Rejected based on amplitude
27m	-14.8	7.5	**3.87**	13	
27n	-14.5	7.6	**3.89**	14	
34a	-14.6	8.9	3.62	1	From plait
34b	-14.4	9.0	3.68	2	
34c	-14.1	9.2	3.67	3	
34d	-14.2	9.1	3.66	4	
34e	-14.5	9.0	3.64	5	
34f	-14.4	8.9	3.64	6	
34g	-14.1	8.9	3.61	7	
34h	-14.3	9.0	3.61	8	
34i	-15.1	9.1	3.62	9	
34j	-14.9	9.3	3.62	10	
34k	-14.7	9.4	3.65	11	
34l	-14.6	9.4	3.64	12	
34m	-14.8	9.2	3.65	13	
34n	-15.0	9.1	3.67	14	
34o	-15.2	8.9	3.68	15	
34p	-14.7	9.0	3.68	16	
34q	-14.2	9.1	3.67	17	
34r	-14.1	8.9	3.65	18	
34s	-14.5	8.8	3.66	19	
34t	-14.2	9.3	3.66	20	
34u	-15.1	8.7	3.66	21	
34v	-15.2	8.6	3.68	22	
34w	-15.0	8.7	3.65	23	
34x	-14.7	8.7	3.67	24	
34y	-14.7	8.6	3.66	25	
34z	-14.6	8.8	3.70	26	
34aa	-14.6	8.7	3.71	27	
34ab	-14.7	8.6	3.72	28	
34ac	-14.5	8.8	3.73	29	
34ad	-15.2	8.7	3.77	30	
34ae	-16.4	8.7	3.79	31	
34-22a	-12.2	8.4	3.60	1	From extension plaited into hair
34-22b	-11.9	8.7	3.57	2	
34-22c	-11.6	8.7	3.53	3	
34-22d	-11.9	8.8	3.54	4	
34-22e	-11.8	8.9	3.54	5	
34-22f	-11.7	8.9	3.54	6	
34-22g	-11.8	9.0	3.53	7	

Table continued...

34-22h	-11.6	9.1	3.53	8	
34-22i	-11.7	9.0	3.54	9	
34-22j	-11.9	8.9	3.54	10	
34-22k	-12.2	9.0	3.52	11	
34-22l	-11.8	9.0	3.50	12	
34-22m	-12.4	8.8	3.48	13	
34-22n	-12.7	8.9	3.49	14	
89a	**-17.5**	**8.9**	3.69	1	Rejected based on amplitude
89b	-17.1	9.3	3.63	2	
89c	-17.2	8.9	3.64	3	
89d	-16.8	8.8	3.66	4	
89e	-16.4	9.0	3.63	5	
89f	-16.3	9.1	3.66	6	
89g	-16.1	9.3	3.71	7	
89h	**-16.0**	**9.5**	3.74	8	Rejected based on amplitude
89i	**-15.8**	**9.2**	3.79	9	Rejected based on amplitude
90a	-12.4	7.9	3.78	1	
90b	-12.3	7.9	3.83	2	
90c	-12.7	7.7	3.81	3	
90d	-13.8	7.5	3.80	4	
90e	-14.1	7.3	3.84	5	
90f	-13.8	7.5	**3.87**	6	
90g	-13.0	7.9	**3.85**	7	
90h	-12.2	8.4	**3.85**	8	
90i	-11.8	8.6	3.84	9	
90j	-11.8	8.6	**3.85**	10	
90k	-11.4	8.7	3.84	11	
90l	-10.9	8.7	3.79	12	
90m	**-11.0**	**8.4**	3.79	13	Rejected based on amplitude
93a	-13.7	6.8	3.79	1	
93b	-13.5	6.8	3.77	2	
93c	-13.3	6.8	3.76	3	
93d	-12.6	7.3	3.71	4	
93e	-12.6	7.4	3.71	5	
93f	-13.1	7.1	3.68	6	
93g	**-13.6**	**7.0**	3.66	7	Rejected based on amplitude
94a	-10.5	11.2	3.59	1	
94b	-10.4	11.4	3.65	2	
94c	-10.4	10.8	3.64	3	
94d	-10.8	10.1	3.64	4	
94e	-11.5	10.0	3.71	5	
94f	-12.2	9.9	3.73	6	
94g	-12.2	10.0	3.69	7	
94h	-12.0	10.0	3.72	8	
94i	-11.7	10.0	3.78	9	

Table continued...

94j	-11.7	10.0	3.78	10	
94k	-11.3	10.2	3.78	11	
94l	-11.3	10.3	3.81	12	
94m	-11.0	10.4	**3.86**	13	
94n	-10.8	10.4	3.80	14	
94o	-10.9	10.3	3.75	15	
94p	-10.8	10.3	3.77	16	
94q	-10.5	10.2	3.79	17	
94r	-10.5	10.1	3.72	18	
94s	-10.6	9.9	3.70	19	
94t	-11.1	9.8	3.76	20	
94u	-11.2	9.7	3.79	21	
94v	-11.2	9.6	3.76	22	
94w	-10.9	9.5	3.74	23	
94x	-10.9	9.4	3.79	24	
94y	**-11.2**	**9.2**	3.75	25	Rejected based on amplitude
98a	-14.1	9.1	3.71	1	
98b	-13.8	9.0	3.70	2	
98c	-14.2	8.7	3.69	3	
98d	-13.8	9.1	3.68	4	
98e	-14.2	8.9	3.69	5	
98f	-14.5	8.6	3.72	6	
98g	-14.6	8.4	3.73	7	
98h	-14.5	8.4	3.73	8	
98i	-14.3	8.8	3.72	9	
98j	-13.8	9.1	3.73	10	
98k	-13.9	8.9	3.75	11	
98l	-14.1	8.7	3.76	12	
98m	-14.2	8.3	3.75	13	
98n	**-13.9**	**8.3**	3.78	14	Rejected based on amplitude
98o	**-13.7**	**8.3**	3.84	15	Rejected based on amplitude
99a	**-15.7**	**7.9**	3.66	1	Rejected based on amplitude
99b	-15.7	7.6	3.65	2	
99c	-15.5	7.3	3.64	3	
99d	-15.2	7.2	3.60	4	
99e	-15.3	7.4	3.58	5	
99f	-15.9	7.0	3.58	6	
99g	-15.9	7.3	3.59	7	
99h	-15.1	7.8	3.60	8	
99i	-14.8	7.8	3.60	9	
99j	-15.2	7.7	3.62	10	
99k	-15.3	7.7	3.67	11	
99l	-15.8	7.8	3.72	12	
99m	**-15.8**	**7.5**	3.71	13	Rejected based on amplitude
100a	**-16.2**	**8.1**	3.58	1	Rejected based on amplitude

Table continued...

100b	-16.0	8.4	3.54	2	
100c	-16.2	8.1	3.52	3	
100d	-16.5	7.9	3.54	4	
100e	-16.5	7.9	3.52	5	
100f	-16.0	8.0	3.54	6	
100g	-15.6	8.4	3.52	7	
100h	-16.0	8.5	3.54	8	
100i	-16.6	8.7	3.54	9	
100j	**-17.1**	**8.2**	3.55	10	Rejected based on amplitude
101a	**-14.8**	**8.5**	3.69	1	Rejected based on amplitude
101b	**-15.6**	**7.3**	3.66	2	Rejected based on amplitude
101c	-15.4	6.8	3.63	3	
101d	-15.9	7.0	3.62	4	
101e	-15.4	7.8	3.63	5	
101f	-15.4	8.2	3.64	6	
101g	-15.7	8.1	3.67	7	
101h	-16.2	7.6	3.72	8	
101i	-14.8	8.1	3.73	9	
101j	-14.4	8.6	3.73	10	
101k	-14.7	8.6	3.73	11	
101l	-14.0	8.9	3.71	12	
101m	-14.0	8.8	3.68	13	
101n	-13.8	8.9	3.67	14	
101o	-13.9	8.7	3.68	15	
101p	-14.7	8.2	3.70	16	
101q	-14.7	7.9	3.69	17	
Cemetery 755 - Middle Horizon					
Individual	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**C:N**	**Distance from scalp (cm)**	**Notes**
20a	**-15.6**	**9.4**	3.52	1	Rejected based on amplitude
20b	-16.0	8.9	3.57	2	
20c	-16.3	8.2	3.66	3	
20d	-16.1	8.3	3.55	4	
20e	-16.7	8.3	3.53	5	
20f	-16.9	8.3	3.58	6	
20g	-16.6	8.3	3.59	7	
20h	**-16.8**	**7.7**	3.48	8	Rejected based on amplitude
21a	-11.4	11.0	3.65	1	
21b	-11.4	10.9	3.70	2	
21c	-11.1	10.5	3.71	3	
21d	-11.4	10.2	3.71	4	
21e	-12.1	9.6	3.72	5	
21f	-11.8	9.5	3.72	6	
21g	-12.0	9.6	3.70	7	

Table continued...

21h	-11.8	9.8	3.69	8	
21i	-11.4	10.0	3.75	9	
21j	-10.9	10.4	3.80	10	
21k	-10.5	10.5	3.80	11	
21l	-10.5	10.5	3.82	12	
21m	-10.4	10.6	*3.89*	13	Accepted with caution
21n	-10.0	10.5	*3.86*	14	Accepted with caution
21o	-10.0	10.5	*3.85*	15	Accepted with caution
21p	-10.1	10.3	*3.88*	16	Accepted with caution
21q	-10.4	10.1	**3.91**	17	
21r	-10.6	9.9	*3.88*	18	Accepted with caution
21s	-11.3	9.5	*3.89*	19	Accepted with caution
21t	-12.2	9.4	*3.88*	20	Accepted with caution
21u	-12.5	9.3	*3.86*	21	Accepted with caution
21v	-12.6	9.3	**3.90**	22	
21w	-12.9	9.1	**3.90**	23	
21x	-12.7	9.0	**3.87**	24	
22a	-13.3	10.9	3.76	1	
22b	-13.9	11.0	3.75	2	
22c	-15.0	10.7	3.75	3	
22d	-15.3	10.5	3.77	4	
22e	-15.5	10.5	3.77	5	
22f	-15.3	10.7	3.79	6	
22g	-14.7	11.0	3.78	7	
22h	-13.6	11.3	3.81	8	
22i	-12.8	11.6	3.82	9	
22j	-12.6	11.6	3.83	10	
22k	-12.2	11.4	3.84	11	
22l	-12.4	11.3	*3.86*	12	Accepted with caution
22m	-12.8	11.3	3.84	13	
22n	-12.5	11.4	3.82	14	
22o	-12.2	11.3	3.82	15	
22p	-11.7	11.0	3.83	16	
22q	-12.4	10.7	3.83	17	
22r	-13.7	10.4	3.83	18	
22s	-15.3	10.5	3.84	19	
22t	-16.0	10.9	3.83	20	
22u	-16.1	11.4	3.83	21	
22v	-16.4	11.4	3.84	22	
22w	-16.4	11.6	3.84	23	
22x	-16.2	11.6	*3.85*	24	Accepted with caution
22y	-16.3	11.2	*3.86*	25	Accepted with caution
22z	-16.0	11.8	*3.86*	26	Accepted with caution
22aa	-15.4	11.8	*3.85*	27	Accepted with caution
22ab	-15.9	11.5	*3.85*	28	Accepted with caution

Table continued...

22ac	-15.8	11.6	*3.85*	29	Accepted with caution
22ad	-15.7	11.5	*3.86*	30	Accepted with caution
22ae	-16.2	10.8	*3.88*	31	Accepted with caution
22af	-15.9	10.9	*3.90*	32	Accepted with caution
22ag	-15.6	10.7	*3.87*	33	Accepted with caution
22ah	-15.4	10.4	*3.88*	34	Accepted with caution
22ai	-14.8	10.6	*3.87*	35	Accepted with caution
22aj	-13.9	10.9	*3.87*	36	Accepted with caution
22ak	-13.7	11.1	*3.88*	37	Accepted with caution
22al	-13.3	10.6	*3.86*	38	Accepted with caution
22am	-12.4	10.8	*3.87*	39	Accepted with caution
22an	-12.5	11.0	*3.88*	40	Accepted with caution
22ao	-12.4	10.7	**3.89**	41	
22ap	-12.4	10.8	**3.96**	42	
22aq	-12.3	11.0	**3.95**	43	
22ar	-13.0	11.2	**3.96**	44	
22as	-14.3	11.6	**3.98**	45	
22at	-14.0	12.4	**3.98**	46	
22au	-13.8	11.9	**4.17**	47	
22av	-15.3	11.7	**4.17**	48	
22aw	-15.7	12.2	**4.37**	49	
22ax	-15.7	12.4	**4.50**	50	
35a	-16.5	8.2	**3.94**	1	
35b	-17.0	8.3	**4.03**	2	
35c	-16.5	8.1	**3.89**	3	
35d	-16.0	8.1	**3.90**	4	
35e	-15.9	8.2	**3.89**	5	
35f	-15.7	8.1	**3.87**	6	
35g	-15.8	7.9	3.85	7	
35h	-15.8	8.0	3.83	8	
35i	-16.1	7.9	3.83	9	
35j	-16.2	7.8	3.82	10	
35k	-16.3	7.9	3.82	11	
35l	-16.3	7.8	3.81	12	
35m	-16.4	7.7	3.79	13	
35n	-16.3	7.8	3.76	14	
35o	-16.2	7.9	3.76	15	
35p	-16.3	8.1	3.72	16	
35q	-16.2	8.3	3.74	17	
35r	-16.1	8.4	3.73	18	
35s	-16.1	8.4	3.70	19	
35t	-16.2	8.2	3.71	20	
35u	-16.0	8.3	3.71	21	
35v	-15.5	8.2	3.69	22	
81a	**-10.6**	**10.9**	3.70	1	Rejected based on amplitude

Table continued...

81b	-10.3	10.9	3.64	2	
81c	-10.3	10.4	3.59	3	
81d	-10.8	9.9	3.64	4	
81e	-11.3	9.5	3.64	5	
81f	-11.8	9.1	3.64	6	
81g	-12.0	9.5	3.66	7	
81h	-12.0	9.5	3.64	8	
81i	-11.8	9.4	3.65	9	
81j	-11.8	9.4	3.73	10	
85a	-13.7	9.2	3.67	1	
85b	-13.3	9.5	3.64	2	
85c	-13.2	9.7	3.63	3	
85d	-12.9	9.7	3.62	4	
85e	-12.9	9.6	3.65	5	
87a	-10.2	9.2	3.64	1	
87b	-9.8	9.3	3.59	2	
87c	-9.7	9.3	3.60	3	
87d	-9.5	9.4	3.59	4	
87e	-9.4	9.4	3.60	5	
87f	-9.4	9.4	3.60	6	
87g	-9.6	9.4	3.61	7	
87h	-9.8	9.1	3.60	8	
87i	-10.2	8.7	3.59	9	
87j	-10.5	8.4	3.62	10	
Cemetery 1003 - Late Intermediate Period					
Individual	**$\delta^{13}C$ (‰)**	**$\delta^{15}N$ (‰)**	**C:N**	**Distance from scalp (cm)**	**Notes**
28a	**-12.1**	**9.9**	3.52	1	Rejected based on amplitude
28b	-12.0	10.2	3.50	2	
28c	-12.2	10.0	3.48	3	
28d	-12.3	9.8	3.48	4	
28e	-12.6	9.6	3.51	5	
28f	-12.5	9.3	3.50	6	
28g	-12.5	9.3	3.48	7	
28h	-12.5	9.2	3.50	8	
28i	-12.5	9.1	3.48	9	
28j	-12.4	9.1	3.48	10	
28k	-12.1	9.3	3.48	11	
28l	-12.3	9.2	3.50	12	
28m	-12.3	9.2	3.51	13	
28n	-12.3	9.4	3.49	14	
28o	-12.5	9.3	3.49	15	
28p	-12.5	9.4	3.51	16	
28q	-12.8	9.1	3.53	17	

Table continued...

28r	**-12.9**	**9.1**	3.50	18	Rejected based on amplitude
28s	**-12.9**	**8.8**	3.51	19	Rejected based on amplitude
28t	**-12.7**	**8.7**	3.45	20	Rejected based on amplitude
30a	-10.7	8.0	3.60	1	
30b	-10.4	8.2	3.62	2	
30c	-10.0	8.6	3.64	3	
30d	-9.9	8.6	3.65	4	
30e	-9.9	8.5	3.63	5	
30f	-9.4	9.0	3.63	6	
30g	-9.0	9.4	3.63	7	
30h	-8.1	10.1	3.63	8	
30i	-7.9	10.0	3.63	9	
30j	-8.0	10.1	3.63	10	
30k	-8.2	10.6	3.64	11	
30l	-8.5	10.6	3.66	12	
30m	-8.7	10.2	3.67	13	
30n	**-9.1**	**10.6**	3.70	14	Rejected based on amplitude
36a	-9.9	11.4	3.58	1	
36b	-10.2	11.2	3.55	2	
36c	-10.2	11.5	3.54	3	
36d	-10.2	11.4	3.56	4	
36e	-10.5	11.3	3.55	5	
36f	-10.7	11.0	3.57	6	
36g	-10.6	10.7	3.56	7	
36h	-10.2	10.6	3.55	8	
36i	-10.3	10.6	3.52	9	
36j	-10.3	10.3	3.54	10	
36k	-9.8	10.5	3.56	11	
36l	-9.3	10.8	3.52	12	
36m	-9.3	11.0	3.53	13	
36n	-9.1	10.9	3.53	14	
36o	-9.2	10.9	3.53	15	
36p	-9.3	11.1	3.53	16	
36q	-9.5	11.3	3.53	17	
36r	-9.7	11.5	3.53	18	
36s	-9.9	11.5	3.53	19	
36t	-10.2	11.0	3.52	20	
36u	-10.3	10.9	3.51	21	
36v	-10.5	10.7	3.54	22	
36w	-10.3	10.7	3.52	23	
36x	-10.0	10.4	3.52	24	
36y	-9.9	10.3	3.51	25	
36z	-10.0	11.5	3.50	26	
36aa	-9.9	10.8	3.54	27	
36ab	-9.7	11.0	3.53	28	

Table continued...

36ac	-9.7	11.0	3.55	29	
36ad	-9.8	10.7	3.54	30	
37a	-11.4	14.1	3.58	1	
37b	-11.7	14.3	3.52	2	
37c	-11.9	14.0	3.51	3	
37d	-12.1	13.8	3.45	4	
37e	-12.7	13.3	3.48	5	
37f	-12.7	12.6	3.47	6	
37g	-13.3	11.4	3.56	7	
37h	**-13.0**	**10.9**	3.48	8	Rejected based on amplitude
37i	**-13.6**	**10.3**	3.45	9	Rejected based on amplitude
37j	**-13.3**	**10.0**	3.41	10	Rejected based on amplitude
37k	**-13.7**	**9.2**	3.31	11	Rejected based on amplitude
37l	**-14.8**	**9.2**	3.01	12	Rejected based on amplitude
39a	-12.2	10.0	3.53	1	
39b	-12.3	9.9	3.51	2	
39c	-12.3	9.8	3.52	3	
39d	-12.3	9.8	3.54	4	
39e	-12.2	9.8	3.53	5	
39f	-12.4	9.9	3.57	6	
39g	-12.5	9.8	3.56	7	
39h	-12.4	9.7	3.58	8	
39i	-12.5	9.5	3.63	9	
39j	-12.6	9.5	3.61	10	
39k	-12.6	9.5	3.63	11	
39l	-12.5	9.7	3.63	12	
39m	-12.4	9.4	3.65	13	
39n	-12.6	9.4	3.62	14	
39o	-12.4	9.4	3.62	15	
39p	-12.4	9.8	3.64	16	
39q	-12.6	9.3	3.65	17	
39r	-12.2	9.4	3.67	18	
39s	-12.1	9.7	3.62	19	
39t	**-12.5**	**9.4**	3.65	20	Rejected based on amplitude
39u	**-12.6**	**9.2**	3.61	21	Rejected based on amplitude
39v	**-13.2**	**8.4**	3.66	22	Rejected based on amplitude
39w	**-13.6**	**8.3**	3.59	23	Rejected based on amplitude
39x	**-13.4**	**8.4**	3.76	24	Rejected based on amplitude
40a	-10.6	9.4	3.45	1	
40b	-10.4	9.4	3.49	2	
40c	-10.3	9.6	3.49	3	
40d	-10.6	9.4	3.48	4	
40e	-10.8	9.2	3.48	5	
40f	-10.8	9.2	3.48	6	
40g	-10.5	9.6	3.45	7	

Table continued...

40h	-10.5	9.6	3.42	8	
40i	**-12.3**	**8.3**	3.41	9	Rejected based on amplitude
41a	-10.3	7.6	3.57	1	
41b	-10.1	7.5	3.59	2	
41c	-10.4	7.3	3.59	3	
41d	-11.0	6.9	3.57	4	
41e	-11.5	6.9	3.56	5	
41f	-11.7	7.0	3.55	6	
41g	-11.7	7.3	3.54	7	
41h	-11.8	7.3	3.51	8	
41i	-11.8	7.5	3.52	9	
41j	-11.3	7.7	3.52	10	
41k	-10.9	8.0	3.55	11	
41l	-10.7	8.1	3.51	12	
41m	-11.0	8.0	3.51	13	
41n	-11.6	7.4	3.51	14	
41o	-12.1	6.9	3.50	15	
41p	-12.8	6.5	3.51	16	
41q	**-13.6**	**5.9**	3.59	17	Rejected based on amplitude
41r	**-16.0**	**5.2**	3.92	18	Rejected based on amplitude
42a	**-13.0**	**8.1**	3.65	1	Rejected based on amplitude
42b	-12.2	7.8	3.53	2	
42c	-12.6	7.5	3.56	3	
42d	-13.3	7.3	3.54	4	
42e	-13.5	7.5	3.50	5	
42f	-13.2	7.8	3.47	6	
42g	-12.9	7.7	3.49	7	
42h	-13.0	7.6	3.50	8	
42i	-13.4	7.5	3.51	9	
42j	-13.8	7.6	3.56	10	
42k	-14.2	7.9	3.60	11	
42l	-14.0	8.2	3.54	12	
42m	**-13.9**	**7.8**	3.56	13	Rejected based on amplitude
47a	-12.3	10.5	3.50	1	
47b	-12.3	10.6	3.53	2	
47c	-12.0	10.5	3.55	3	
47d	-12.1	10.4	3.55	4	
47e	-12.1	10.2	3.58	5	
47f	-12.2	10.2	3.59	6	
47g	-12.4	10.1	3.62	7	
47h	-12.5	9.9	3.63	8	
47i	-12.5	9.6	3.64	9	
47j	-12.6	9.6	3.65	10	
47k	-12.4	9.6	3.68	11	
47l	-12.2	9.7	3.68	12	

Table continued...

47m	-11.9	9.8	3.69	13	
47n	-11.9	9.9	3.70	14	
47o	-12.0	9.9	3.68	15	
47p	-12.3	9.9	3.70	16	
47q	-12.6	9.8	3.71	17	
47r	-12.6	9.7	3.70	18	
47s	-12.6	9.9	3.70	19	
47t	-12.5	10.0	3.73	20	
47u	-12.7	9.7	3.73	21	
47v	**-12.7**	**9.6**	3.72	22	Rejected based on amplitude
74a	**-9.6**	**9.1**	3.66	1	Rejected based on amplitude
74b	-9.6	9.4	3.56	2	
74c	-9.4	9.1	3.54	3	
74d	-9.7	8.6	3.54	4	
74e	-9.7	8.4	3.61	5	
74f	-10.0	8.6	3.60	6	
74g	-10.6	8.5	3.67	7	
74h	-11.3	8.2	3.65	8	
74i	-11.9	8.1	3.66	9	
74j	-11.7	8.1	3.65	10	
74k	-11.3	8.1	3.60	11	
74l	-10.9	8.3	3.63	12	
74m	-10.3	8.9	3.63	13	
74n	-9.8	9.4	3.58	14	
74o	**-9.8**	**9.4**	3.65	15	Rejected based on amplitude
74p	**-9.9**	**9.4**	3.66	16	Rejected based on amplitude
74q	**-10.1**	**8.7**	3.67	17	Rejected based on amplitude
75a	**-14.5**	**6.6**	3.41	1	Rejected based on amplitude
75b	**-14.5**	**6.8**	3.44	2	Rejected based on amplitude
75c	-14.2	7.0	3.47	3	
75d	-14.1	7.1	3.44	4	
75e	-13.8	8.6	3.44	5	
75f	-13.6	7.3	3.45	6	
75g	-13.3	7.4	3.43	7	
75h	-13.4	7.2	3.45	8	
75i	-13.8	6.9	3.44	9	
75j	-14.1	6.5	3.43	10	
75k	-13.9	6.7	3.43	11	
76a	**-13.2**	**8.5**	3.52	1	Rejected based on amplitude
76b	**-13.3**	**8.4**	3.47	2	Rejected based on amplitude
76c	-13.4	8.4	3.53	3	
76d	-13.5	8.3	3.53	4	
76e	-13.2	8.3	3.50	5	
76f	-13.4	8.2	3.53	6	
76g	-13.8	8.0	3.53	7	

Table continued...

76h	-14.0	7.8	3.54	8	
76i	-13.7	7.9	3.57	9	
76j	-13.5	8.1	3.55	10	
76k	-13.8	7.9	3.58	11	
76l	-14.0	7.9	3.60	12	
76m	-13.6	8.1	3.56	13	
76n	-13.1	8.6	3.58	14	
76o	-12.9	8.8	3.58	15	
76p	-13.0	8.9	3.58	16	
76q	-13.1	9.2	3.60	17	
76r	-13.2	8.9	3.59	18	
76s	-13.4	8.7	3.57	19	
76t	-13.9	8.2	3.60	20	
76u	**-14.0**	**7.6**	3.59	21	Rejected based on amplitude
76v	**-15.8**	**6.0**	3.49	22	Rejected based on amplitude
77a	-11.4	10.5	3.64	1	
77b	-10.7	10.6	3.65	2	
77c	-10.8	10.8	3.65	3	
77d	-10.8	10.7	3.68	4	
77e	-10.4	10.1	3.66	5	
77f	-10.3	9.5	3.66	6	
77g	-10.3	9.3	3.69	7	
77h	-10.4	9.1	3.70	8	
77i	-10.5	9.6	3.74	9	
77j	-10.9	9.4	3.70	10	
77k	-10.8	9.7	3.69	11	
77l	-10.6	9.8	3.67	12	
77m	-10.7	9.5	3.66	13	
77n	-10.5	9.0	3.63	14	
77o	-10.8	9.2	3.65	15	
77p	-10.8	9.0	3.67	16	
77q	-10.9	8.7	3.66	17	
77r	-11.3	8.5	3.67	18	
77s	-11.6	8.4	3.68	19	
77t	-12.0	8.1	3.68	20	
77u	-11.9	8.3	3.69	21	
77v	-12.1	9.1	3.64	22	
77w	-11.8	8.2	3.68	23	
77x	-11.8	8.3	3.69	24	
77y	-11.5	8.1	3.66	25	
77z	-11.4	7.8	3.63	26	
77aa	-11.3	8.4	3.70	27	
77ab	-11.4	8.3	3.70	28	
77ac	-11.4	8.3	3.68	29	
77ad	-11.4	8.5	3.71	30	

Table continued...

77ae	-11.5	8.5	3.72	31	
77af	-11.4	8.6	3.71	32	
77ag	-11.4	8.2	3.67	33	
77ah	-11.6	8.5	3.74	34	
77ai	-11.5	8.5	3.74	35	
77aj	-11.4	8.5	3.74	36	
77ak	-11.2	8.7	3.74	37	
77al	-11.1	8.7	3.73	38	
77am	-11.3	8.6	3.73	39	
77an	-11.2	8.4	3.67	40	
77ao	-11.3	8.5	3.67	41	
77ap	-11.5	8.4	3.68	42	
77aq	-11.6	8.4	3.65	43	
77ar	-11.5	8.4	3.60	44	
78a	-11.4	10.7	3.44	1	
78b	-11.3	10.4	3.43	2	
78c	-11.9	9.4	3.45	3	
78d	-11.9	9.2	3.43	4	
78e	-11.7	9.0	3.43	5	
78f	-11.7	8.8	3.41	6	
78g	-11.8	8.3	3.43	7	
78h	**-12.0**	**8.1**	3.50	8	Rejected based on amplitude
80a	-11.7	8.8	3.60	1	
80b	-11.5	9.0	3.59	2	
80c	-11.1	8.3	3.62	3	
80d	-10.3	9.0	3.62	4	
80e	-9.9	9.0	3.61	5	
80f	-9.8	9.1	3.63	6	
80g	-9.4	9.1	3.62	7	
80h	-9.1	8.9	3.61	8	
80i	-9.2	8.9	3.60	9	
80j	-9.5	8.9	3.63	10	
80k	-9.9	9.0	3.61	11	
80l	-10.2	9.0	3.61	12	
80m	-10.5	9.1	3.62	13	
80n	-10.5	9.3	3.62	14	
80o	-10.3	9.4	3.62	15	
80p	-10.1	9.6	3.63	16	
80q	-9.8	9.8	3.63	17	
80r	-9.5	10.0	3.64	18	
80s	-9.3	10.3	3.65	19	
80t	-9.3	10.3	3.66	20	
80u	-9.2	10.4	3.66	21	
80v	-9.0	10.3	3.66	22	
80w	-9.0	10.2	3.66	23	

Table continued...

80x	-9.2	10.2	3.68	24	
80y	-9.3	10.0	3.69	25	
80z	-9.4	9.8	3.69	26	
80aa	-9.5	9.8	3.66	27	
120a	-12.7	8.4	**4.06**	1	
120b	-12.5	8.6	3.83	2	
120c	-12.4	9.1	3.81	3	
120d	-12.5	9.2	3.84	4	
120e	-12.7	9.2	3.83	5	
120f	-13.1	8.8	3.81	6	
120g	-13.0	8.7	3.78	7	
120h	-11.8	9.9	3.76	8	
120i	-11.1	10.6	3.76	9	
120j	-11.0	10.5	3.75	10	
120k	-10.9	10.3	3.75	11	
120l	-10.9	10.0	3.74	12	
120m	-10.7	9.7	3.73	13	
120n	-11.1	9.5	3.75	14	
120o	-11.6	9.3	3.76	15	
120p	-12.4	8.9	3.77	16	
120q	-12.6	8.8	3.79	17	
120r	-12.1	9.3	3.81	18	
120s	-12.1	8.8	**3.88**	19	
120t	-12.7	8.1	3.84	20	
120u	-12.8	8.1	**3.88**	21	
120v	-12.4	8.6	**3.92**	22	
120w	-11.9	9.0	**4.07**	23	
120x	-12.6	7.7	**4.46**	24	
121a	**-10.9**	**8.3**	3.45	1	Rejected based on amplitude
121b	-10.6	8.4	3.52	2	
121c	-10.5	8.3	3.51	3	
121d	-11.4	7.8	3.48	4	
121e	-12.4	8.0	3.46	5	
121f	-12.2	7.9	3.44	6	
121g	-11.1	7.9	3.40	7	
121h	**-10.2**	**7.7**	3.39	8	Rejected based on amplitude

Appendix 5 Faunal Isotopic Results

Values highlighted in bold were deemed to be of unacceptable quality and the sample was not used in the main analysis.

Cemetery 1001 - Early Horizon											
Individual	**Species**	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**1σ**	**Mean $\delta^{15}N$ (‰)**	**1σ**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Notes**
AN1	Camelid	Bone	-15.3	0.0	6.9	0.0	3	3.17	16.6	Lower leg bone, ulna?	
AN2	Fish	Bone									Not run, too small and brittle
AN3	Camelid	Wool	-14.1	0.2	6.1	0.1	3	3.47			
AN10	Camelid	Bone	-12.6	0.0	6.1	0.0	3	3.25	22.8	Carpal/tarsal	
Cemetery 1002 - Early Horizon											
Individual	**Species**	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**1σ**	**Mean $\delta^{15}N$ (‰)**	**1σ**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Notes**
AN40	Camelid	Bone	-15.7	0.0	5.5	0.0	3	3.29	14.1	Metapodial	
AN41	Camelid	Bone	-16.8	0.0	9.6	0.1	3	3.25	12.0	Humerus	
AN42	Camelid	Bone	-10.7	0.1	7.1	0.0	3	3.54	7.8	Vertebra	
Cemetery 1004 (all from Sector B) - Early Horizon											
Individual	**Species**	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**1σ**	**Mean $\delta^{15}N$ (‰)**	**1σ**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Notes**
AN4	Camelid	Bone	-13.8	0.0	7.3	0.0	3	3.28	11.7	Humerus		
AN5	Camelid	Bone	-18.8	0.0	10.3	0.1	3	3.25	2.6	Diaphysis?		
AN6	Camelid	Bone	-11.8	0.1	8.4	0.0	3	3.30	17.3	Metapodial		
AN7	Camelid	Bone	-16.6	0.0	4.0	0.0	3	3.29	12.6	Long bone		
AN8	Camelid	Bone	-17.1	0.1	6.6	0.0	3	3.58	15.1	Vertebra		
AN9	Camelid	Bone	-15.2	0.0	7.3	0.0	3	3.46	20.3	Vertebra		
AN11	Bird	Bone	-12.6	0.0	17.6	0.1	3	3.42	22.3	Vertebra		
AN12	*Sula variegata*	Bone	-11.3	0.0	15.8	0.2	3	3.22	21.3	Humerus		
AN13	*Sigmodon* sp.	Bone	-15.0	0.1	11.0	0.0	3	3.39	7.9	Skull		

Table continued...

AN14	Camelid	Bone	-14.5	0.6	20.9	0.1	3	**4.20**	8.2	Podial		
AN15	Sulidae family	Bone	-11.6	0.1	15.4	0.1	3	3.21	17.8	Skull		
AN16	Camelid	Tooth	-17.0	0.0	8.2	0.1	3	3.19	16.7		UPM4	
Cemetery 734 - Early Intermediate Period												
Individual	**Species**	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**1σ**	**Mean $\delta^{15}N$ (‰)**	**1σ**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Notes**
AN38	Camelid	Bone	-14.9	0.0	9.6	0.0	3	3.24	9.2	Skull		
AN39a	Camelid	Bone	-14.7	0.1	9.0	0.1	3	3.26	20.3	Mandible		
AN39b		Tooth	-15.3	0.1	10.6	0.0	3	3.19	13.8		LdPM4	
Cemetery 398 - Middle Horizon												
Individual	**Species**	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**1σ**	**Mean $\delta^{15}N$ (‰)**	**1σ**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Notes**
AN36a	Camelid	Bone	-15.8	0.0	6.8	0.0	3	3.26	19.7	Mandible		
AN36b		Tooth	-16.4	0.1	8.8	0.1	3	3.27	5.8		LM2	
AN37a	*Lycalopex* sp.?	Bone	-16.2	0.0	7.2	0.0	3	3.16	21.7	Mandible		
AN37b		Tooth	-16.5	0.1	8.9	0.0	3	3.17	18.9		LC	
Cemetery 755 - Middle Horizon												
Individual	**Species**	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**1σ**	**Mean $\delta^{15}N$ (‰)**	**1σ**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Notes**	
AN29	Camelid	Bone	-17.4	0.0	5.4	0.0	3	3.18	22.3	Scapula		
AN30	Camelid	Bone	-18.8	0.1	8.1	0.1	3	3.13	18.1	Long bone, ulna?		
AN31	Camelid	Bone	-14.4	0.1	7.1	0.0	3	3.20	22.2	Os coxae		
AN32	Camelid	Bone	-18.8	0.0	8.9	0.0	3	3.14	19.3	Vertebra		
AN33	Camelid	Bone	-11.9	0.0	6.1	0.0	3	3.24	22.3	Scapula		
AN34	Camelid	Bone	-13.5	0.1	8.0	0.1	3	3.26	13.9	Femur		
AN35	Camelid	Bone	-15.8	0.0	6.8	0.1	3	3.14	21.3	Vertebra		

Table continued...

Cemetery 1003 - Late Intermediate Period												
Individual	**Species**	**Tissue**	**Mean $\delta^{13}C$ (‰)**	**1σ**	**Mean $\delta^{15}N$ (‰)**	**1σ**	**No. of reps**	**Mean C:N**	**Yield (%)**	**Bone type**	**Tooth type**	**Notes**
AN17	Camelid	Bone	-12.5	0.0	6.2	0.0	3	3.44	21.1	Mandible		
AN18	Camelid	Bone	-15.2	0.0	6.1	0.0	3	3.16	22.3	Vertebra		
AN19a	Camelid	Wool	-20.1	0.1	8.7	0.2	3	3.42				
AN19b		Bone	-18.7	0.0	7.6	0.1	3	3.16	21.3	Metapodial		
AN20a	Camelid	Tooth	-15.9	0.0	8.7	0.1	3	3.15	10.3		LM1	
AN20b		Bone	-15.6	0.0	7.4	0.0	3	3.16	20.2	Mandible		
AN21	Camelid	Bone	-16.1	0.0	6.2	0.0	3	3.19	17.8	Metapodial		
AN22	Camelid	Bone	-19.1	0.2	6.6	0.0	3	3.19	20.2	Tibia		
AN23a	Camelid	Wool	-18.7	0.0	7.9	0.1	3	3.51				
AN23b		Bone	-16.3	0.1	5.7	0.0	3	3.19	22.0	Metapodial		
AN24	Camelid	Bone	-17.0	0.0	5.4	0.0	3	3.21	22.0	Scapula		
AN25	Camelid	Wool	-20.3	0.3	7.0	0.0	3	3.29				
AN26	Dog	Bone	-10.7	0.0	10.1	0.0	3	3.23	19.2	Femur		
AN27	Camelid	Bone	-12.4	0.0	8.3	0.0	3	3.18	21.8	Vertebra		
AN28	Camelid	Bone	-18.5	0.0	7.4	0.0	3	3.13	20.3	Metapodial		

Appendix 6 Samples from Middle Horizon Hair Pieces

Three plaits from separate hair pieces were collected - two (individuals 33 and 35) from Cemetery 755 and one (individual 34) from Cemetery 398. The hair pieces were made up of plaits attached to plain woven cotton textile (see Figure 1.1). The samples were ascribed 'individual' numbers although it is acknowledged that they could have been, and in the case of Individuals 33 and 34, were made of composited pieces. All of the hair used was human hair.

Figure1.1 Individual 35 hair piece.

Individual 33 was too brittle to un-plait but appeared to be constructed in a similar manner to Individual 34.

Individual 34 was constructed of 23 separate parts. The initial part of the plait was long (31cm). After this point groups of shorter hair strands (c. 8cm in length), folded into an 'n' shape were plaited in to extend the plait (see Figure 1.2). A total of 22 extension pieces were added. The initial part of the plait and the last extension piece were analysed isotopically (referred to as 34 and 34E respectively).

Individual 35 was a plait with no extensions.

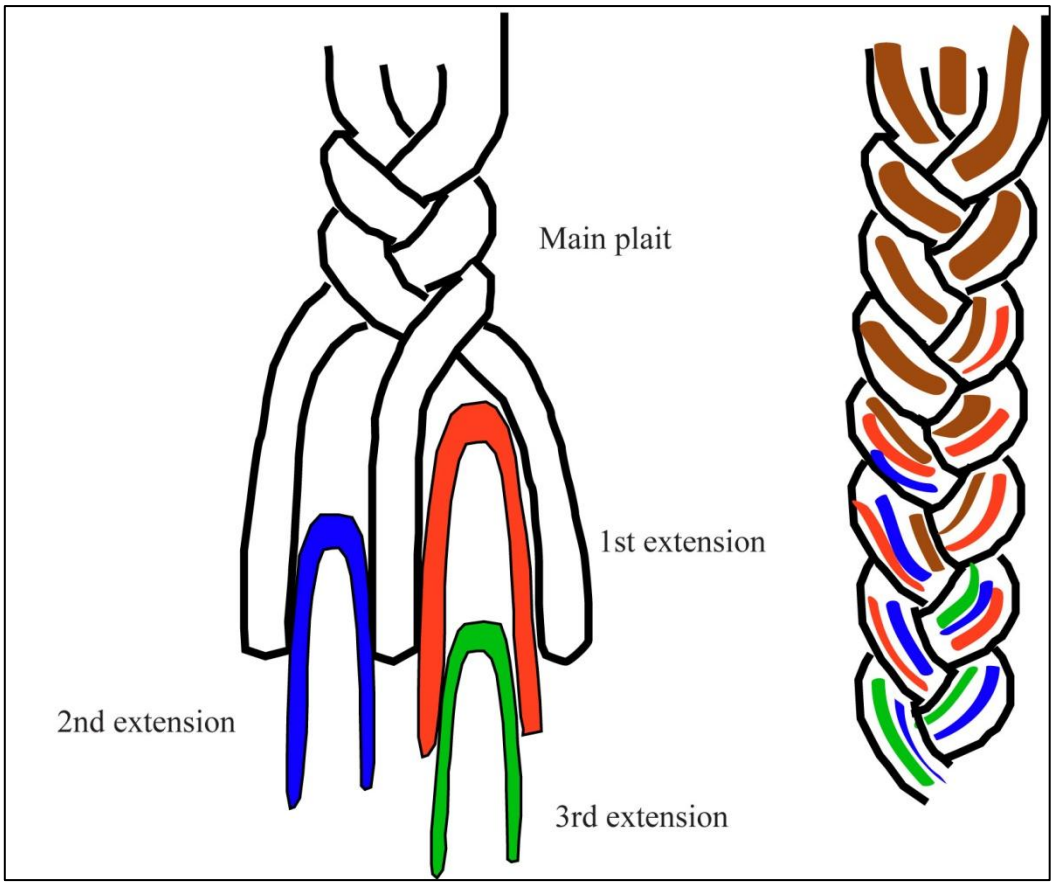

Figure 1.2 Details of how the extensions were plaited into the hair. Left, the manner in which the extensions were added. Right, the plaited hair with the strands coloured to demonstrate how the were plaited together.